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A MANUAL

OF

PRACTICAL HYGIENE

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BY

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PREFACE TO THE SEVENTH EDITION.

In the present Edition some changes have been made in the arrangement of the chapters, so as to suit better the Course of Lectures as given at Netley, and thus secure a more natural sequence of subjects. The principal processes for analysis of water, air, &c., have been placed in a separate section at the end, which it is hoped will be found convenient. I regret that prolonged illness has obliged me to delay the appearance of the work longer than I had intended. I take this opportunity of acknowledging the kind assistance I have received from my friend and colleague, Surgeon A. M. Davies, M.S., Assistant Professor of Hygiene, Army Medical School.

F. de CHAUMONT.

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INTRODUCTION.

Hygiene is the art of preserving health; that is, of obtaining the most perfect action of body and mind during as long a period as is consistent with the laws of life. In other words, it aims at rendering growth more perfect, decay less rapid, life more vigorous, death more remote.

This art has been practised from the earliest times. Before Hippocrates there were treatises on hygiene, which that great master evidently embodied in his incomparable works. It was then based on what we should now call empirical rules, viz., simply on observations of what seemed good or bad for health. Very early, indeed, the effects of diet and of exercise were carefully noticed, and were considered the basis of hygiene.[1] Hippocrates, indeed, appears to have had a clear conception of the relation between the amount of food taken and of the mechanical energy produced by it; at least, he is extremely careful in pointing out that there must be an exact balance between food and exercise, and that disease results from excess either way.

The effects on health of different kinds of air, of water, and to some extent of soils, were also considered at a very early date, though naturally the ignorance of chemistry prevented any great advance in this direction. Hippocrates summed up the existing knowledge of his time on the six articles, which in after-days received the absurd name of the "Non-naturals."[2] The six articles, whose regulation was considered indispensably necessary to the life of man, were—air, aliment, exercise and rest, sleep and wakefulness, repletion and evacuation, the passions and affections of the mind.

With the exception of the attempts of the alchemists, and of the chemical physicians, to discover some agent or drug which might increase or

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[1] Herodicus, one of the preceptors of Hippocrates, was the first to introduce medicinal gymnastics for the improvement of health and the cure of disease; though gymnastics in training for war had been used long before. Plutarch says of him that, labouring under a decay which he knew could not be perfectly cured, he was the first who blended the gymnastic art with physic, in such a manner as protected to old age his own life and the lives of others afflicted with the same disease. He was censured by Plato for keeping alive persons with crazy constitutions.—*Mackenzie on Health.*

[2] This title originated in a sentence of Galen, and was introduced into use by the jargon of the Peripatetic school. It was employed in all treatises on hygiene for probably nearly 1500 years.

strengthen the principle of life,[1] the practice of hygiene remained within the same limits until physiology (the knowledge of the laws of life) began to be studied. Hygiene then began to acquire a scientific basis. Still retaining its empirical foundation drawn from observation, it has now commenced to apply the discoveries of physiology to the improvement of health, and to test the value of its own rules by this new light. It is now gradually becoming an art based on the science of physiology, with whose progress its future is identified.

But the art of hygiene has at present still another object. If we had a perfect knowledge of the laws of life, and could practically apply this knowledge in a perfect system of hygienic rules, disease would be impossible. But at present disease exists in a thousand forms, and the human race languishes, and at times almost perishes, under the grievous yoke. The study of the causes of disease is strictly a part of physiology,[2] but it can only be carried out by the practical physician, since an accurate identification of the disease is the first necessary step in the investigation of causes.

The causes being investigated, the art of hygiene then comes in to form rules which may prevent the causes or render the frame more fitted to bear them; and as in the former case it was the exponent of physiology, in this case it becomes the servant of the pathologist.

Taking the word hygiene in the largest sense, it signifies rules for perfect culture of mind and body. It is impossible to dissociate the two. The body is affected by every mental and moral action; the mind is profoundly

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[1] It was when chemistry was being rudely studied by the alchemists that an entirely different school of hygiene arose. The discovery of chemical agents, and the great effect they produce on the body, led to the notion that they could in some way aid the forces of life, and insure a prolonged, if not an eternal youth, and a life of ages instead of one of years. This belief, the natural result of the discovery of new powers, has not yet entirely died out; and while there are some who still look to every fresh agent as possibly containing "the balsam of life," there are also still enthusiasts who search the mystic tomes of the alchemists or the Rosicrucians in the faith that, after all, the great secret was really found. It may be worth while to consider the idea which underlay the dreams of the alchemists. Life was looked on as an entity or principle liable to constant waste, and to eventual expenditure. If some agent could be found to arrest the waste, to crystallise, as it were, the tissues in their full growth and vigour, decay, it was conceived, would be impossible, and youth would be eternal. In other cases, it was supposed that the agent would itself contain the principle of life, and therefore would at once restore destroyed health, and recall again departed youth. We now know this idea to be wrong in every point. The constant decay the alchemists sought to check is life itself, for life is but incessant change, and what we call decay is only a metamorphosis of energy. To arrest the changes in the body for one single moment would be death, or, short of death, it would be lessening of the energy which is the expression of life. Nor is there any hope that the extension of the period of vital energy can ever be accomplished except by improving the nutrition of the tissues. Here, indeed, it is just possible that, in time to come, drugs will aid hygiene, either by better preparing food for the purposes of nutrition, or by removing or preventing those chemical changes in the tissues which we call decay. But at present, certainly, no rules can be laid down for the use of drugs in hygiene, except in that debatable land which lies between hygiene and the practice of medicine, that is, in that uncertain region which we do not like to call disease, and yet which is not health.

[2] Physiology and pathology are, in fact, one; normal and abnormal life, regular and irregular growth and decay, must be studied together, just as, in fact, human physiology is imperfect without the study of all the other forms of life, animal and vegetable, which are in the world. Separated for convenience, these various studies will finally converge.

influenced by bodily conditions. For a perfect system of hygiene we must train the body, the intellect, and the moral faculties in a perfect and balanced order.

But is such a system possible?

Is there, or will there ever be, such an art, or is the belief that there will be, one of those dreams which breathe a blind hope into us, a hope born only of our longings, and destined to die of our experience? And, indeed, when we look around us and consider the condition of the world—the abundance of life, its appalling waste; the wonderful contrivances of the animal kingdom, the apparent indifference with which they are trampled under foot; the gift of mind, its awful perversion and alienations; and when, especially, we note the condition of the human race, and consider what it apparently might be, and what it is: its marvellous endowments and lofty powers; its terrible sufferings and abasement; its capacity for happiness, and its cup of sorrow; the boon of glowing health, and the thousand diseases and painful deaths,—he must indeed be gifted with sublime endurance or undying faith who can still believe that out of this chaos order can come, or out of this suffering happiness and health.

Whether the world is ever to see such a consummation no man can say; but as ages roll on hope does in some measure grow. In the midst of all our weaknesses, and all our many errors, we are certainly gaining knowledge, and that knowledge tells us, in no doubtful terms, that the fate of man is in his own hands.

It is undoubtedly true that we can, even now, literally choose between health or disease; not, perhaps, always individually, for the sins of our fathers may be visited upon us, or the customs of our life and the chains of our civilisation and social customs may gall us, or even our fellow-men may deny us health, or the knowledge which leads to health. But, as a race, man holds his own destiny, and can choose between good and evil; and as time unrolls the scheme of the world it is not too much to hope that the choice will be for good.

Looking only to the part of hygiene which concerns the physician, a perfect system of rules of health would be best arranged in an orderly series of this kind.

The rules would commence with the regulation of the mother's health while bearing her child, so that the growth of the new being should be as perfect as possible. Then, after birth, the rules (different for each sex at certain times) would embrace three epochs:[1] of growth (including infancy and youth); of maturity, when for many years the body remains apparently

[1] First expressly noted by Galen.

stationary; of decay, when, without actual disease, though, doubtless in consequence of some chemical changes, molecular feebleness and death commence in some part or other, forerunning general decay and death.

In these several epochs of his life, the human being would have to be considered—

1*st*, In relation to the natural conditions which surround him, and which are essential for life, such as the air he breathes; the water he drinks; his food, the source of all bodily and mental acts; the soil which he moves on, and the sun which warms and lights him, &c.; in fact, in relation to nature at large.

2*nd*, In his social and corporate relations, as a member of a community with certain customs, trades, conditions of dwellings, clothing, &c.; subjected to social and political influences, sexual relations, &c.

3*rd*, In his capacity as an independent being, having within himself sources of action, in thoughts, feelings, desires, personal habits, all of which affect health, and which require self-regulation and control.

Even now, incomplete as hygiene necessarily is, such a work would, if followed, almost change the face of the world. But would it be followed?

In some cases the rules of hygiene could not be followed, however much the individual might desire to do so. For example, pure air is a necessity for health; but an individual may have little control over the air which surrounds him, and which he must draw into his lungs. He may be powerless to prevent other persons from contaminating his air, and thereby striking at the very foundation of his health and happiness. Here, as in so many other cases which demand regulation of the conduct of the individuals toward each other, the State steps in for the protection of its citizens, and enacts rules which shall be binding upon all. Hence arises what is now termed "State Medicine," a matter of the greatest importance. The fact of "State Medicine" being possible marks an epoch in which some sanitary rules receive a general consent, and indicates an advancing civilisation. Fear has been expressed lest State Medicine should press too much on the individual, and should lessen too much the freedom of personal action. This, however, is not likely, as long as the State acts cautiously, and only on well-assured scientific grounds, and as long as an unshackled Press discusses with freedom every step.[1]

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[1] A watchful care over the health of the people, and a due regulation of matters which concern their health, is certainly one of the most important functions of Government. The fact that, in modern times, the subject of hygiene generally, and State Medicine in particular, has commenced to attract so much the public attention, is undoubtedly owing to the application of statistics to public health. It is impossible for any nation, or for any Government, to remain indifferent when, in figures which admit of no denial, the national amount of health and happiness, or disease and suffering, is determined. The early Statistical Reports of the Army by Tulloch, Marshall, and Balfour directed attention to the importance of this matter. The establishment of the Registrar-General's office in 1838, and the commencement of the

There are, however, some cases in which the State cannot easily interfere, though the individual may be placed under unfavourable hygienic conditions by the action of others. For example, in many trades, the employed are subjected to danger from the carelessness, or avarice, or ignorance of the employers. Every year the State is, however, very properly more and more interposing and shielding the workman against the dangers which an ignorant or careless master brings on him.

But in other cases the State can hardly interpose with effect; and the growth of sanitary knowledge and the pressure of public opinion alone can work a cure, as, for example, in the case of the dwellings of our poorer classes. In many parts of the country the cottages are unfit for human beings; in many of our towns the cupidity of builders runs up houses of the most miserable structure, for which there is unhappily no lack of applicants; or masters oblige their men to work in rooms or to follow plans which are most detrimental to health.

But even in such cases it will be always found that self-interest would really indicate that the best course is that we should do for our neighbours as for ourselves. Analyse also the effect of such selfishness and carelessness as has been referred to on the nation at large, and we shall find that the partial gain to the individual is far more than counterbalanced by the injury to the State, by the discontent, recklessness, and indifference produced in the persons who suffer, which may have a disastrous national result. It is but too commonly forgotten that the whole nation is interested in the proper treatment of every one of its members, and in its own interest has a right to see that the relations between individuals are not such as in any way to injure the well-being of the community at large.

In many cases, again, the employer of labour finds that, by proper sanitary care of his men, he reaps at once an advantage in better and more zealous

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system of accurately recording births and deaths, will hereafter be found to be, as far as the happiness of the people is concerned, one of the most important events of our time. We owe a nation's gratitude especially to him to whose sagacity the chief fruits of the inquiry are due, to William Farr.

Another action of the Government in our day was scarcely less important. It is impossible to overrate the value of the Government Inquiry into the Health of Towns, and of the country generally, which was commenced forty years ago by Edwin Chadwick, Southwood Smith, Neil Arnott, Sutherland, Guy, Toynbee, and others, and has, in fact, been continued ever since by the official successors of these pioneers, the former medical officer to the Privy Council, Mr Simon, the late Dr Seaton, and the present medical officer of the Local Government Board, Dr Buchanan. Consequent on this movement came the appointment of medical officers of health to the different towns and parishes. The reports published by many of these gentlemen have greatly advanced the subject, and have done much to diffuse a knowledge of hygiene among the people, and at the same time to extend and render precise our knowledge of the conditions of national health. When the effect of all these researches and measures develops itself, it will be seen that even great wars and political earthquakes are really nothing in comparison with these silent social changes. Even now legislation, such as the Public Health Act, 1875, and the various measures since passed, is beginning to exert a deep influence. Legislation, and action based on legislation, can only proceed slowly, and we must be satisfied if there be a continual advance, though it may not be so rapid as some desire.

work, in fewer interruptions from ill health, &c., so that his apparent outlay is more than compensated.

This is shown in the strongest light by the army. The State employs a large number of men, whom it places under its own social and sanitary conditions. It removes from them much of the self-control with regard to hygienic rules which other men possess, and is therefore bound by every principle of honest and fair contract to see that these men are in no way injured by its system. But more than this: it is as much bound by its self-interest. It has been proved over and over again that nothing is so costly in all ways as disease, and that nothing is so remunerative as the outlay which augments health, and in doing so augments the amount and value of the work done.

It was the moral argument as well as the financial one which led Lord Herbert to devote his life to the task of doing justice to the soldier, of increasing the amount of his health, and moral and mental training, and, in so doing, of augmenting not only his happiness, but the value of his services to the country.

BOOK I.

CHAPTER I.

SOILS.

CHOICE OF SITES.

The term soil is used here in a large sense, to express all the portion of the crust of the earth which by any property or condition can affect health. The subdivision into surface soil and subsoil is often very useful; and these terms need no definition.

SECTION I.

CONDITIONS OF SOIL AFFECTING HEALTH.

Soil consists of mineral, vegetable, and often animal substances, in the interstices of which are also air and often water.

In reviewing the conditions which affect health, it will be convenient to commence with the air and the water in soils.

Sub-Section I.—The Air in the Soil.

The hardest rocks alone are perfectly free from air; the greater number even of dense rocks, and all the softer rocks, and the loose soils covering them, contain air. The amount is in loose sands often 40 or 50 per cent.; in soft sandstones, 20 to 40 per cent. The loose soil turned up in agricultural operations may contain as much as 2 to 10 times its own volume of air.

The nature of the air in soils has been examined by a good many observers; it is mostly very rich in carbon dioxide, is very moist, and probably contains effluvia and organic substances, derived from the animal or vegetable constituents, which have not yet been properly examined. Occasionally it contains carburetted hydrogen, and in most soils, when the water contains sulphates, a little hydrogen sulphide may be found. It has been examined by Nichols[1] in America, Fleck[2] in Dresden, Fodor[3] in Buda-

[1] *Sixth Report of Board of Health*, Massachusetts, 1875.

[2] 4ter and 5ter *Jahresbericht der chemischen Centralstelle*, Dresden, 1876.

[3] *Deutsche Vierteljahrschrift für öffentliche Gesundheit.*, Band vii. p. 205, 1875; also *Hygienische Untersuchungen ueber Luft, Boden, und Wasser*, von Dr Josef Fodor, Braunschweig, 1882.

Pesth, Lewis and Cunningham[1] in Calcutta, and many others. Nichols made his experiments in the Back-Bay lands of Boston, Massachusetts,—land made by throwing gravel upon sea mud. His first series of experiments was upon air drawn from depths of 3¾ to 5½ feet. There was no hydrogen sulphide, and only a little ammonia; the CO_2 was from 1·49 to 2·26 volumes per 1000, and varied inversely as the height of the ground water, which was very near the surface. This relation, however, was not constant at a depth of 6 to 10 feet. Fleck found at 2 metres the CO_2 29·9 per 1000, and the oxygen 163·3; at 6 metres the CO_2 79·6, and the oxygen 148·5. Fodor found (out of 13 observations) at 1 metre from 8·99 to 10·39 of CO_2, and oxygen from 187·97 to 213·35; at 4 metres (11 observations) from 26·31 to 54·45 CO_2, and oxygen from 179·06 to 185·32. The great amount of CO_2 points to very intense chemical changes in the ground, especially in the deep strata, but at the same time it may be very variable in different places. The amount of oxygen was in a measure inversely as the CO_2. At a depth of 4 metres (13 feet) the air would be irrespirable, and would extinguish a light. (How many cellars go as deep as 13 feet into the ground, and the cellar air feeds the house with air!) From the examination of the organic matter, he comes to the conclusion that it is not necessarily its oxidation on the spot that produces the CO_2, and that therefore the latter cannot be taken, except under certain conditions, as a measure of impurity, depending as it does to a large extent upon the *permeability* of the soil. He found no hydrogen sulphide, but a good deal of nitric acid and ammonia, the relative quantities depending upon free access of air or otherwise. As regards moisture, the mean percentage of humidity was 80·7 at 2 metres and 93·8 at 4. Lewis and Cunningham, in their observations at Calcutta, found results somewhat similar to those of Fodor, the CO_2 being greatest in the lower strata examined. The composition of soil air differs at different times and seasons, the absolute and relative amounts of the constituents varying under varying conditions.

Professor Wollny[2] shows that the amount of CO_2 depends upon the factors of the decomposition of organic matter (heat, moisture, and porosity) as affected by the physical nature of the ground and its covering, and on the physical resistance that the ground presents to its escape. The CO_2 is at its maximum when the slopes are at 20°, and southern have more than northern, though the difference is not great, heat and moisture counteracting each other. In drought northern slopes have most CO_2. With equal quantities of organic matter there is more CO_2 the more granular the soil, and such soil prevents the passage of CO_2 downwards as well as upwards. The air in ground shaded by living plants has considerably less CO_2 than that in bare ground, and in the latter it has less (in dry years, not in wet) than in ground covered by dead parts of plants.

The amount of air in soils can be roughly estimated, in the case of rather loose rocks, by seeing how much water a given bulk will absorb, which can be done by the following plan:—Weigh a piece of dry rock, and call its weight W: then weigh it in water and call this weight W_1: then take it out of the water saturated with moisture, and weigh it again: call this weight W_2. We then have—

$$\frac{(W_2 - W)100}{W - W_1} = \text{percentage of air.}$$

Example.—A piece of dry rock weighs 100 grammes (W): when weighed in

[1] *The Soil in its Relation to Disease*, Calcutta, 1875.
[2] *Nature*, Jan. 6, 1887, p. 230 (from *Naturforscher*).

water it weighs 60 (W_1); weighed out of water, but saturated, it weighs 110 (W_2): then $\frac{110-100}{100-60}=\frac{10}{40}=0{\cdot}25$, and this multiplied by 100 gives 25 per cent. of porosity.

When the soil is loose, Pettenkofer adopts the following plan:—Dry the loose soil at 212° Fahr. (100° Cent.), and powder it, but without crushing it very much; put it into a burette, and tap it so as to expel the air from the interstices as far as possible; connect another burette by means of an elastic tube with the bottom of the first burette and clamp it on close to the end of the latter; pour water into No. 2 burette, and then, by pressing the clamp, allow the water to rise through the soil until a thin layer of water is seen above it; then read off the amount of water thus gone out of the second burette. The calculation—

$$\frac{\text{Amount of water used} \times 100}{\text{Cubic centimetres of dry soil}} = \text{percentage of air.}$$

Example.—30 c.c. of soil were put in the burette: it took 10 c.c. of water to reach to the top: then $\frac{10 \times 100}{30} = 33{\cdot}3$ per cent. of porosity.

Renk's plan is very simple. Take a measured quantity of soil, say 50 c.c., shaken well together, so as to represent its natural condition as much as possible, and put it into a 200 c.c. graduated glass measure: then pour in 100 c.c. of water, and shake well so as to expel all air. Allow it to stand a little, and read off the point at which the water stands. Suppose it stands at 125 c.c., then the 50 c.c. of soil and the 100 c.c. of water, when shaken together, only occupy a space of 125 c.c., the difference, 25 c.c., representing the bulk of air displaced from the 50 c.c. of soil: therefore $\frac{25}{50} \times 100 = 50$ per cent. of air or porosity in the sample of soil.

The subterranean atmosphere thus existing in many loose soils and rocks is in continual movement, especially when the soils are dry; the chief causes of movement are the diurnal changes of heat in the soil, and the fall of rain, which must rapidly displace the air from the superficial layers, and, at a later date, by raising the level of the ground water, will slowly throw out large quantities of air from the soil. Fodor considers the temperature of the air, the ground temperature, the action of the winds, rainfall, barometric pressure, and level of ground water to be all influential in causing movement of the ground air, and consequent relative change in its constituents. As far as the CO_2 was concerned, Lewis and Cunningham found that the air temperature and wind were both inoperative, whilst the moisture had the greatest influence on the upper strata, and the ground water on the lower.

Local conditions must also influence the movement; a house artificially warmed must be continually fed with air from the ground below, and doubtless this air may be drawn from great depths. Coal gas escaping from pipes, and prevented from exuding by frozen earth on the surface, has been known to pass sideways for some distance into houses.[1] The air of cesspools and of porous or broken drains will thus pass into houses, and the examination of drains alone often fails to detect the cause of effluvia in the house.

The unhealthiness of houses built on "made soils," for some time after the soils are laid down, is no doubt to be attributed to the constant ascent of impure air from the impure soil into the warm houses above.

[1] *Lancet*, 1873, vol. ii. p. 592.

To hinder the ascent of air from below into a house is therefore a sanitary point of importance, and should be accomplished by paving and concreting the basement, or, in some cases, by raising the house on arches off the ground. The improvement of the health of towns, after they are well paved, may be partly owing to lessening of effluvia, though partly also to the greater ease of removing surface impurities. In some malarious districts great benefit has been obtained by covering the ground with grass, and thus hindering the ascent of the miasm.

As a rule, it is considered that loose porous soils are healthy, because they are dry, and, with the qualification that the soil shall not furnish noxious effluvia from animal or vegetable impregnation, the rule appears to be correct. It is, however, undoubted that dry and apparently tolerably pure soils are sometimes malarious, and this arises either from the soils being really impure, or from their porosity allowing the transference of air from considerable distances. Even on the purest soils it is desirable to observe the rule of cutting off the subsoil air from ascent into houses.

The diseases which have been attributed to telluric effluvia are—

Paroxysmal fevers.	Bilious remittent fever.
Enteric (typhoid) fever.	Cholera.
Yellow fever.	Dysentery.

The questions connected with these effluvia will be noticed farther on.

The Water in the Soil.

The water present in soils is divided into moisture and ground water. When air as well as water is present in the interstices the soil is merely moist. The ground water must be defined, with Pettenkofer, as that condition in which all the interstices are filled with water, so that, except in so far as its particles are separated by solid portions of soil, there is a continuity of water. Other definitions of ground water have been given, but it is in this sense it is spoken of here.

Moisture of Soil.—The amount of moisture depends on the power of the soil to absorb and retain water, and on the supply of water to the soil either from rain or ground water. With respect to the first point, almost all soils will take up water. Pfaff[1] has shown that dried quartz sand on a filter can take up as much as 20 per cent. of water, and, though in the natural condition in the soil the absorption would not be so great, there is no doubt that even the hardest sands retain much moisture. After several months of long continued drought, Mr Church found a light calcareous clay loam subsoil to contain from 19 to 28 per cent. of water.

A loose sand may hold 2 gallons of water in a cubic foot, and ordinary sandstone may hold 1 gallon. Chalk takes 13 to 17 per cent.; clay, if not very dense, 20; humus, as much as 40 to 60, and retains it strongly. The so-called "cotton-soil" of Central India, which is derived from trap rock, absorbs and retains water with great tenacity; the driest granite and marbles will contain from ·4 to 4 per cent. of water, or from 5 to 50 pints in each cubic yard.

The moisture in the soil is derived partly from rain, to which no soil is absolutely impermeable, as even granite, clay slate, and hard limestone may absorb a little. Practically, however, soils may be divided into the impermeable (unweathered granite, trap and metamorphic rocks, clay slate,

[1] *Zeitsch. für Biologie*, Band iv. p. 249.

dense clays, hard oolite, hard limestone and dolomite, &c.) and permeable (chalk, sand, sandstone, vegetable soils, &c.). The amount of rain passing into the soil is influenced, however, by other circumstances—by the declivity and inclination of the soil; by the amount of evaporation, which is increased in summer; by hot winds; and by the rapidity of the fall of rain, which may be greater than the soil can absorb. On an average, in this country, about 25 per cent. of the rain penetrates into the sand rock, 42 per cent. into the chalk, and from 60 to 96 per cent. into the loose sands. The rest evaporates or runs off the surface by the lines of natural drainage. The rapidity with which the rain water sinks through soil evidently varies with circumstances; in the rather dense chalks it has been supposed to move 3 feet downwards every year, but in the sand its movement must be much quicker.

The moisture of the soil is not, however, derived solely from the rain; the ground water by its own movement of rising and falling, by evaporation from the surface of the subterranean water, and by capillary attraction, makes the upper layers of the soil wet. By these several agencies the ground near the surface is in most parts of the world kept more or less damp.

Determination of Moisture in the Soil.—By drying 10 grammes at a temperature of 220° Fahr. (104°·4 Cent.), then weighing, exposing to air, and observing the increase of weight, an idea is formed of the amount of moisture, and of the hygrometric properties of the soil. If the dried soil is put over water under a bell jar, it will be exposed to air saturated with moisture, or by observing the dry and wet bulb thermometers, the humidity of the air at the time can be noted.

The Ground or Subsoil Water.—The subterranean continuous water, known as *ground* or *subsoil water*, is at very different depths below the surface in different soils; sometimes it is only 2 or 3 feet from the surface, in other cases as many hundreds. This depends on the compactness or permeability of the soil, the ease or difficulty of outflow, and the existence or not of an impermeable stratum near or far from the surface. It is an error to look upon the ground water as a subterranean lake or sea, with an even surface like an ordinary sheet of water, for it is not necessarily horizontal, and in some places it may be brought nearer to the surface than others by peculiarities of ground. The water is in constant movement, in most cases flowing towards the nearest water-courses or the sea; the rate of movement has not yet been perfectly determined. In Munich Pettenkofer reckons its rate as 15 feet daily; the high water in the Elbe moves the ground water in the vicinity at the rate of about 7 or 8 feet daily. Fodor [1] gives the mean rate at Buda-Pesth as 53 metres (174 feet), with a maximum of 66 metres (216 feet) in twenty-four hours, reckoning by the rise of the wells following the rise of the Danube.

The rate of movement is not influenced solely by compactness or porosity of soil, or inclination. The roots of trees exert a great influence in lessening the flow; and, on the other hand, water runs off more rapidly than before in a district cleared of trees. The level of the ground water is constantly changing. It rises or falls more or less rapidly and at different rates in different places; in some cases its movement is only a few inches either way, but in most cases the limits between its highest and lowest levels in the year are several feet (in Munich about 10). In India the changes are greater. At Saugor, in Central India, the extremes of the soil water are

[1] *Op. cit.*, Bd. ii. p. 98.

from a few inches from surface (in the rains) to 17 feet in May. At Jubbulpore it is from 2 feet from the surface to 12 or 15.

The *causes of change* in the level of the ground water are the rainfall, pressure of water from rivers or the sea, and alterations in outfall, either increased obstruction or the reverse. The effect of the rainfall is sometimes only traceable weeks or even months after the fall, and occasionally, as in plains at the foot of hills, the level of the ground water may be raised by rainfalls occurring at great distances. The pressure of the water in the Rhine has been shown to affect the water in a well 1670 feet away. The pressure of the Danube at Buda-Pesth is found to influence a well at a distance of 2700 feet (Fodor).

In a place near the Hamble River (Hampshire) the tide was found to affect the water of a well at a distance of 2240 feet, the well itself being 83 feet deep and 140 feet above mean water-level.[1]

Diseases connected with Moisture and Ground Water.—Dampness of soil may presumably affect health in two ways—1*st*, by the effect of the water, *per se*, causing a cold soil, a misty air, and a tendency in persons living on such a soil to catarrhs and rheumatism; and 2*nd*, by aiding the evolution of organic emanations. The decomposition which goes on in a soil is owing to four factors, viz., presence of decomposable organic matters (animal or vegetable), heat, air, and moisture. These emanations are at present known only by their effects; they may be mere chemical agencies, but there is increasing reason to believe that they are caused by low forms of life which grow and propagate in these conditions. At any rate, moisture appears to be an essential element in their production. The ground water is presumed to affect health by rendering the soil above it moist, either by evaporation or capillary attraction, or by alternate wettings and dryings.

A moist soil is cold, and is generally believed to predispose to rheumatism, catarrh, and neuralgia. It is a matter of general experience that most persons feel healthier on a dry soil.

In some way which is not clear, a moist soil produces an unfavourable effect on the lungs: at least in a number of English towns which have been sewered, and in which the ground has been rendered much drier, Buchanan has shown that there has been a diminution in the number of deaths from "phthisis."[2] Dr Bowditch of Boston (U.S.) and Dr Middleton of Salisbury noticed the same fact many years ago. Buchanan's evidence is very strong as to the fact of the connection, but the nature of the link between the two conditions of drying of soil and lessening of certain pulmonary diseases is unknown. It is curious how counter the observation runs to the old and erroneous view that in malarious (and therefore wet) places there is less phthisis.

A moist soil influences greatly the development of the agent, whatever it may be, which causes the paroxysmal fevers. The factors which must be present to produce this agent are heat of soil (which must reach a certain point = isotherm of 65° Fahr. of summer air temperature), air, moisture, and some impurity of soil, which in all probability is of vegetable nature. The rise and fall of the ground water, by supplying the requisite degree of moisture, or, on the contrary, by making soil too moist or too dry, evidently

[1] *Lectures on State Medicine*, by F. de Chaumont (Smith and Elder), p. 91, 1875.

[2] Buchanan, *Ninth and Tenth Reports of the Medical Officer to the Privy Council*, 1866, p. 48, and 1867, p. 57. As the term "phthisis" is a general one, and includes all the fatal diseases of the lungs, with destruction of lung-tissue (tuberculous and inflammatory), as well as other cases of wasting, with pulmonary symptoms, it would be well to translate the word "phthisis" by the phrase "wasting diseases of the lungs."

plays a large part in producing or controlling periodical outbreaks of paroxysmal fevers in the so-called malarious countries. The development of malaria may be connected either with rise or with fall of the ground water. An impeded outflow which raises the level of the ground water has, in malarious soils, been productive of immense spread of paroxysmal fevers. In the making of the Ganges and Jumna Canals the outflow of a large tract of country was impeded, and the course and extent of the obstruction was traced by Dempster and Taylor by the almost universal prevalence of paroxysmal fevers and enlarged spleens in the inhabitants along the banks.[1] The severe and fatal fever which prevailed in Burdwan, in Lower Bengal, for a number of years, appears to have been in part owing to the obstruction to the natural drainage from mills and from blockage of water-courses.[2] In some cases relative obstruction comes into play; *i.e.*, an outfall sufficient for comparatively dry weather is quite inadequate for the rainy season, and the ground water rises. At Pola, in Istria, for example, there are no marshes, but in the summer sometimes half, sometimes 90 per cent. of all cases are malarious; the reason is, that a dense clay lies a little below an alluvial soil, and the only exit for the rain is through two valley-troughs, which cannot carry off the water fast enough in the wet season,[3] from February to May.

A remarkable instance of excessive rainfall, causing an outbreak of malarial disease, occurred at Kurrachee, in Scinde, in 1869. The average annual rainfall in Scinde in 11 years (1856–66) was only 6·75 inches; and the greatest rainfall in that time was 13·9 inches (1863). In 1867 the rainfall was 2·73, in 1868 it was 3·36 inches; while in 1869 it reached the unprecedented amount of 28·45 inches; of which 13·18 fell in July and 8·39 inches in September. April, May, October, November, and December were rainless. The 1st Batt. 21st Regiment had the following attacks of paroxysmal fever per 1000 of strength:—In April, none; in May, 9; in June, 39; in July, 30; in August, 93; in September, 105; in October, 198; in November, 1004; and in December, 644. In December the regiment was embarked for Madras, as it had "thoroughly lost heart." The disease was not fatal, as the death-rate for the year, from all causes, was only 25·7 per 1000. At Kurrachee, as the rainfall is usually so small, the ground dries fast, and is then non-malarious. The ground is flat, and there is no subsoil drainage. In 1866, when there was heavy rainfall (13·75 inches), there was also a development of malarial disease, which was continued in 1867.

The opposite result, viz., an increased outflow lowering the subsoil water, has been observed in drainage operations, and very malarious places have been rendered quite healthy by this measure, as in Lincolnshire, and many parts of England. The case of Boufarie, in Algeria, is a good instance. Successive races of soldiers and colonists had died off, and the station had the worst reputation. Deep drainage was resorted to; the level of the

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[1] The observations of Dempster and Taylor on the Jumna Canal have been more recently confirmed by Ferguson (*Sanitary Administration of the Punjab* for 1871, Appendix IV.), who has investigated the effect on malarious disease on the Bári Doáb Canal District; he found canal irrigation increased malarious fever, apparently by raising the soil-water levels.

[2] Dr Derby (*Third Report of the State Board of Health of Massachusetts*, Boston, 1872) points out how ague has been produced by obstructions to outflow, such as tide-mills, &c. So long ago as 1828 authority to remove a dam was obtained on account of injury to health. See also case recorded by Dr Cattell in Natal, *Army Medical Reports*, vol. xiii., 1871, p. 178, produced by natural causes.

[3] Dr Jilck, in *Archiv der Heilk.*, 1870, p. 493.

ground water was lowered less than 2 feet. This measure, and a better supply of drinking water, reduced the mortality to one-third.

A case mentioned by Pettenkofer[1] is also very striking as to the effect of subsoil drainage on some kind of fever in horses. Two royal stables near Munich, with the same arrangements as to stalls, food, and attendance, and the same class of horses, suffered very unequally from fever; horses sent from the unhealthy to the healthy stables did not communicate the disease. The difference between the two places was, that in the healthy stables the ground water was 5 to 6 feet, in the unhealthy only 2½ feet from the surface. Draining the latter stables, and reducing the ground water to the same height, made these stables as healthy as the others.

Enteric fever has also been supposed to be connected with changes in moisture of the soil, owing to rising and falling of the ground water. Professor Pettenkofer's observations on the wells of Munich led Buhl to the discovery that in that city there is a very close relation between the height of the ground water and the fatal cases of enteric fever;[2] the outbreaks of enteric fever occurred when the ground water was lowest, and especially when, after having risen to an unusual height, it had rapidly fallen. Pettenkofer has repeated and extended the inquiry with the same results. The point has been also numerically investigated by Seidel[3] in Munich and Leipzig for the years 1856–64 and 1865–73, and from a mathematical consideration of the numbers he concludes that, according to the theory of probabilities, it is 36,000 to 1 that there is, in each period, a connection between the two occurrences.[4] Other observations in Germany are confirmatory,[5] but in this country the connection has not been traced. In some outbreaks of enteric fever the ground water has been rising and not falling. Fodor[6] says that at Buda-Pesth the rise of enteric fever mortality accompanies the rising ground water, and the two fall together. In other instances the attacks have been traced to impure drinking water or milk, to sewer emanations, or to personal contagion, and the agency of the ground water has appeared to be quite negative. Dr Buchanan[7] has quoted a case in which the sinking of the ground water and the outbreak of fever were coincident, and yet the connection was, so to speak, accidental, for the efficient cause of the outbreak was the poisoning of the drinking water with enteric evacuations. And he also points out that when the

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1 Quoted by Kirchner, *Lehrb. der Mil.-Hygiene*, 1869, pp. 217, 218.

2 *Zeitschrift für Biologie*, Band i. p. 1.

3 *Zeitsch. für Biologie*, Band i. p. 221, and Band ii. p. 145.

4 Ranke, however, pointed out that no enteric fever existed in the neighbourhood of Munich but what was imported from Munich, although soil and ground water were the same. Munich has a soil consisting of fine sand, with a peculiar power of holding nitrogenous substances; it was provided with cesspools, from which more than 90 per cent. of the contents soaked into the surrounding soil, and, as the streets were well paved, the houses were the only outlets for the foul soil-air.

Virchow, in his Report on the Sewerage of Berlin, showed that the mortality was greatest in July and August, the curve corresponding accurately with the variation of the ground water, the death-rate being greatest at the lowest level; this was chiefly due to deaths under one year. At the lowest level there was every year a little epidemic of enteric fever. At Zürich in 1872 the results were directly opposed to Pettenkofer's views (see *Lectures on State Medicine*, p. 101). Geissler considers the influence of the rise and fall of the ground water a local matter, and agrees with Rudolph Rath in attributing the enteric fever of Berlin to contaminated water. The case of water transmission (which he quotes from Hägler) in the village of Lausen is a very conclusive one. (*Schmidt's Jahrbüch.*, 1874, No. 2, 185; also *Archiv für Klin. Medicin*, 1873, p. 237; see also an abstract in the Report on Hygiene, *Army Med. Reports*, vol. xv. p. (197).

Vogt of Bern (*Trinkwasser oder Bodengase*) strongly supports Pettenkofer's views, and considers the propagation by drinking water as illusory.

5 Buxbaum, "Der Typhus in der Kaserne zu Neustift," *Zeitsch. für Biologie*, Band vi. p. 1. This seems strong evidence in favour of Pettenkofer's view.

6 *Op. cit.*

7 *Medical Times and Gazette*, March 1870.

ground water has actually been lowered in certain English towns by drainage operations, enteric fever has not increased as it should do, according to theory, but has diminished, owing to the introduction of pure water from a distance. He thus thinks that, while a connection between the prevalence of enteric fever and sinking of the ground water must be admitted to exist, it is indirect, and the true cause of the fever is impurity of the drinking water. Pettenkofer has replied to this view,[1] and denies, from actual analysis, the fact of the contamination of the drinking water in enteric outbreaks.

At the present moment the observations of Pettenkofer, and the case of the barracks at Neustift, recorded by Buxbaum, are certainly in favour of the opinion that a direct connection may exist in some cases between the sinking of the ground water and outbreaks of enteric fever; but the frequency and extent of the connection remains to be determined, and in this country, at any rate, the other conditions of spread of enteric fever appear to be far more common.

Assuming the truth of the connection, the other conditions which Pettenkofer considers necessary, besides a rapid sinking of ground water after an unusual rise, are impurity of the soil from animal impregnation, heat of soil, and the entrance of a specific germ.[2]

A very similar view is held by Pettenkofer in respect of cholera, and he has advanced many striking arguments[3] to show that, while sporadic cases of cholera may occur, there will be no widespread epidemic unless certain conditions of soil are present, viz., an impure porous soil, which has recently been rendered moist by a rise of ground water, and then has been penetrated by air during the fall of ground water, and into which the specific germ (*Keim*) of cholera has found its way.[4]

In Germany Pettenkofer's views on the spread of cholera have not met with universal acceptance,[5] though there are several instances in support. In India the weight of the evidence is at present against Pettenkofer's view;[6] but, as investigations are now going on which will in a few years settle the point, it is desirable at present to refrain from forming a decided opinion, except in so far that we may feel sure that the singularly localised outbreaks which sometimes occur in India are quite unconnected with any subsoil-water variations.

In the report of MM. Lewis and Cunningham (*op. cit.*) it is shown that the cholera at Calcutta in 1873–4 followed the curve of the ground water-level inversely, exactly in accordance with Pettenkofer's views.

Baldwin Latham[7] endeavours to show that the healthiest periods (*i.e.*, as regards immunity from enteric fever, &c.) are those where the ground

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[1] *Medical Times and Gazette*, June 1870; and *Vierteljahrschrift für öffentliche Gesundsheitspflege*, 1870, Band ii. pp. 176, 197.

[2] *Vierteljahrschrift für öffentl. Ges.*, Band ii. p. 181.

[3] Among his many Essays, special reference may be made to his Analysis of the "Reasons of the Immunity of Lyons from Cholera," *Zeitsch. für Biol.*, Band iv. p. 400.

[4] It is, of course, to be understood that the impurity which aids in producing cholera is derived from persons ill with the disease. For a discussion on Pettenkofer's views on this point, see Report on Hygiene for 1872, in the *Army Med. Department Report*, vol. xiii. (1873); and for his latest views, vol. xxii. (1882) pp. 251 *et seq.*

[5] A careful analysis of this subject is contained in F. Küchenmeister's work (*Verbreitung der Cholera*, 1872), and the work by F. Sander (*Unters über die Cholera*, 1872). Dr Frank (health officer of Munich) believes that the cholera in 1873–4 was imported from Vienna, and points out that in 1873 the ground water and death-rate were not in accordance with Pettenkofer's theory (see Report on Hygiene, *Army Med. Report*, vol. xv. p. 203).

[6] Townsend's Reports on the Cholera in Central India contain so many cases where ground water could have had no influence that it appears impossible to accept Pettenkofer's theory.

[7] Address to the Architectural and Engineering Section, York Congress of Sanitary Institute of Great Britain, 1886 (see vol. viii. of *Transactions San. Inst.*).

water is high; whereas low ground water periods, especially when an exceptionally low period occurs, are the most unhealthy. As a rule, however, he says that the state of the ground water is an indication of the future health rather than of the present, the most unhealthy time being when percolation commences after the lowest ground water period. Thus enteric fever deaths at Croydon (1837–86) are fewest in June, and increase steadily to a maximum in January. This corresponds to the observations of M. Durand-Claye in Paris (1865–69 and 1872–81), who has shown that the deaths from enteric fever are at their lowest in June, and at their highest from August to November. These run in some measure contrary to Pettenkofer's views.

Baldwin Latham lays stress upon the uniformity of ground water as necessary for health. On the whole, we may state the case thus: A uniformly low ground water is most healthy, but a uniformly high ground water is preferable to one that is fluctuating, especially if the limits be wide. It must, however, be borne in mind that it is not the ground water itself that is the cause of disease, but the impurities in the soil which the varying level of the ground water helps to set in action.

Dysentery and the so-called bilious remittent fevers, which occur in foul camps and on ground largely contaminated by animal impurities, may be conjectured to be also influenced by variations in the ground water, but satisfactory evidence has not yet been given. In the Calcutta Report, above cited, the maximum of fever corresponds with the maximum of CO_2 in the soil atmosphere, and with the highest ground-water level. Dysentery, on the other hand, showed two maxima, one at the rise of the water-level, and the other at the corresponding point of the fall.

Fodor[1] states that at Buda-Pesth cholera, enteritis, and intermittent fever appear to be connected with the processes which go on in the upper layer of the soil, and cholera mortality rises and falls inversely with the ground-water level, according to Pettenkofer's view. Enteric fever, on the other hand, appears to be connected with the processes which go on in the lowest stratum of the soil, its mortality varying directly with the ground-water level. The lowest-lying parts of the city have the most impure soil, and are specially subject to cholera, enteritis, and enteric fever; whilst measles, scarlet fever, croup, and diphtheria appear to invade all parts of the city indifferently.

Measurement of the Ground Water.—The height at which water stands in wells is considered to give the best indication of the height of the ground water. Professor Pettenkofer uses a rod on which are fixed a number of little cups, and, when let down into the well and drawn up again, the uppermost cup which contains water marks, of course, the height of the water; the length of the cord or rod used for letting down the cups being known, the changing level of the well can be estimated to within half an inch. Some precautions are necessary in making these observations: if a rope is used it may stretch with use, or in a hot dry wind, or contract in wet weather, and thereby make the observation incorrect; local conditions of wells, proximity to rivers, &c., must be learnt, else what may be termed local alterations in a well may be wrongly supposed to mean changes in the general level of the ground water. It is necessary, therefore, to make the observations simultaneously in many wells and over a considerable district. The observations should be made not less often than once a fortnight, and oftener if possible, and be carried on for a considerable time before any conclusions are drawn.

[1] *Op. cit.*

Pettenkofer also uses a large float which is suspended by a chain travelling over a pulley: this supports an indicator at its other end, which marks the height on a fixed scale.

Method of rendering Soil Drier.—There are two plans of doing this,—deep drainage and opening the outflow. The laying down of sewers often carries off water by leaving spaces along the course of the sewers, but this is a bad plan; it is much better to have special drains for ground water laid by the side of or under the sewers. Deep soil drainage (the drains being from 8 to 12 feet deep and 10 to 20 feet apart) is useful in all soils except the most impermeable, and in the tropics should be carried out even on what are apparently dry sandy plains.

In some cases soil may be rendered drier by opening the outflow. This is an engineering problem which physicians can only suggest. The clearing of water-courses, removal of obstructions, and formation of fresh channels are measures which may have an effect over very large areas which could not be reached by ordinary drainage.

Sub-Section II.

Solid Constituents of the Soil.

There are certain general features which can be conveniently considered first.

1. *Conformation and Elevation.*—The relative amounts of hill and plain; the elevation of the hills; their direction; the angle of slope; the kind, size, and depth of valleys; the chief watersheds, and the direction and discharge of the water-courses; the amount of fall of plains, are the chief points to be considered.

Among the hills the unhealthy spots are enclosed valleys, punch-bowls, any spot where the air must stagnate; ravines, or places at the head or entrance of ravines.

In the tropics especially ravines and nullahs are to be avoided, as they are often filled with decaying vegetation, and currents of air frequently traverse them. During the heat of the day the current of air is up the ravine, at night down it. As the hills cool more rapidly than the surrounding plains, the latter current is especially dangerous, as the air is at once impure and cold. The worst ravine is a long narrow valley, contracted at its outlet, so as to dam up the water behind it. A saddleback is usually healthy, if not too much exposed; so are positions near the top of a slope. One of the most difficult points to determine in hilly regions is the probable direction of winds; they are often deflected from their course, or the rapid cooling of the hills at night produces alteration.

On plains the most dangerous points are generally at the foot of hills, especially in the tropics, where the water, stored up in the hills and flowing to the plain, causes an exuberant vegetation at the border of the hills.

A plain at the foot of hills may be healthy, if a deep ravine cuts off completely the drainage of the hill behind it.

The next most dangerous spots are depressions below the level of the plain, and into which therefore there is drainage. Even gravelly soils may be damp from this cause, the water rising rapidly through the loose soil from the pressure of higher levels.

Elevation acts chiefly by its effect in lessening the pressure of the air, and in increasing the rapidity of evaporation. It has a powerful effect on

marshes, high elevations lessening the amount of malaria, partly from the rapid evaporation, partly from the greater production of cold at night. Yet malarious marshes may occur at great elevations, even 6000 feet (Erzeroum and Mexico).

2. *Vegetation.*—The effect of vegetation on ground is very important. In cold climates the sun's rays are obstructed, and evaporation from the ground is slow; the ground is therefore cold and moist, and the removal of wood renders the climate milder and drier. The extent to which trees impede the passage of water through the soil is considerable.

In hot countries vegetation shades the ground and makes it cooler. The evaporation from the surface is lessened; but the evaporation from the vegetation is so great as to produce a perceptible lowering effect on the temperature of a place. Pettenkofer has calculated that an oak tree, which had 711,592 leaves, had during the summer months (May–October) an evaporation equal to 539·1 centimetres (= 212 inches), while the rainfall was only 65 centimetres (= 25·6 inches); so that the evaporation was $8\frac{1}{3}$ times the rainfall; this shows how much water was abstracted from the soil, and how the air must have been moistened and cooled. Observations in Algeria (Gimbert) have shown that *Eucalyptus globulus* absorbs and evaporates 11 times the rainfall; extremely malarious places being rendered healthy in this way in four or five years.

The hottest and driest places in the tropics are those divested of trees.[1]

Vegetation produces also a great effect on the movement of air. Its velocity is checked; and sometimes in thick clusters of trees or underwood the air is almost stagnant. If moist and decaying vegetation be a coincident condition of such stagnation, the most fatal forms of malarious disease are produced.

Vegetation may thus do harm by obstructing the movement of air; on the other hand, it may guard from the currents of impure air. The protective influence of a belt of trees against malaria is most striking.

In a hygienic point of view, vegetation must be divided into herbage, brushwood, and trees; and these should be severally commented on in reports.

Herbage is always healthy. In the tropics it cools the ground, both by obstructing the sun's rays and by aiding evaporation; and nothing is more desirable than to cover, if it be possible, the hot sandy plains of the tropics with close-cut grass.

Brushwood is frequently bad, and should often be removed. There is, however, evidence that the removal of brushwood from a marsh has increased the evolution of malaria, and that, like trees, brushwood may sometimes offer obstruction to the passage of malaria. It must also be remembered that its removal will sometimes, on account of the disturbance of the ground, increase malarious disease for the time; and therefore, in the case of a temporary camp in a hot malarious country, it is often desirable to avoid disturbing it. When removed, the work should be carried on in the heat of the day, *i.e.*, not in the early morning or in the evening.

Trees should be removed with judgment. In cold countries they shelter

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[1] It has been proposed (by Mr Milne Home) to plant trees at Malta, with the view of improving and regulating the water-supply.

Mr Robert L. Stevenson has considered the thermal influence of forests, in a paper in the *Proceedings of the Royal Society of Edinburgh* (19th May 1873). Single trees act as bad conductors; the air of forests is generally cooler than free air, and certainly cooler than cleared lands; forests heat the air during the day and chill it at night.

from cold winds; in hot they cool the ground; in both they may protect from malarious currents. A decided and pernicious interference with the movement of air should be almost the only reason for removing them. In some of the hottest countries of the world, as in Southern Burmah, the inhabitants place their houses under the trees with the best effects; and it was a rule with the Romans to encamp their men under trees in all hot countries.

The kind of vegetation, except as being indicative of a damp or dry soil, does not appear to be of importance.

Absorption of Heat.—The heat of the sun is absorbed in different amounts by different soils equally shielded or unshielded by vegetation. The colour of the soil and its aggregation seem chiefly to determine it. The dark, loose, incoherent sands are the hottest; even in temperate climates Arago found the temperature of sand on the surface to be 122° Fahr., and at the Cape of Good Hope Herschel observed it to be no less than 159°.[1] The heating power of the sun's rays is indeed excessive. In India the thermometer placed on the ground and exposed to the sun will mark 160° (Buist), while 2 feet from the ground it will only mark 120°. Buist thinks that if protected from currents of air it would mark 212° when placed on the ground. The absorbing and radiating powers of soil are not necessarily equal, though they may be so. Generally the radiating power is more rapid than the absorbing; soils cool more rapidly than they heat. Some of the marshes in Mexico cool so rapidly at night that the evolution of malaria is stopped, and the marsh is not dangerous during the night. A thermometer marked 32° Fahr. on the ground, while 16 feet above the ground it marked 58° Fahr. (Jourdanet).

In Calcutta Lewis and Cunningham[2] found that the temperature of the soil varied with the season. In hot weather the thermometer stood highest in the air, next highest in the upper stratum of the soil, and lowest in the lower stratum. In cold weather the conditions were exactly reversed, the air being coolest and the lowest stratum of soil the hottest. During rain, however, these relations were not constant.

With regard to absorbing power, the following table by Schübler contains the only good experiments at present known :—

Power of retaining Heat, 100 being assumed as the standard.

Sand with some lime,	100	Clayey earth,	68·4
Pure sand,	95·6	Pure clay,	66·7
Light clay,	76·9	Fine chalk,	61·8
Gypsum,	72·2	Humus,	49
Heavy clay,	71·11		

The great absorbing power of the sands is thus evident, and the comparative coldness of the clays and humus. Herbage lessens greatly the absorbing power of the soil, and radiation is more rapid. On the Orinoco a naked granite rock has been known to have a temperature of 118° Fahr., while an adjacent rock covered with grass had a temperature 32° lower.

In cold countries, therefore, the clayey soils are cold, and as they are also damp, they favour the production of rheumatism and catarrhs; the sands are, therefore, the healthiest soils in this respect. In hot countries the sands are objectionable from their heat, unless they can be covered with

[1] *Meteorology*, p. 4. [2] *Op. cit.*

grass. They sometimes radiate heat slowly, and therefore the air is hot over them day and night.

The sun's rays cause two currents of heat in soil: one wave diurnal, the heat passing down in temperate climates to about 4 feet in depth during the day, and receding during the night—the depth, however, varying with the nature of the soil and with the season; the other wave is annual, and in temperate climates the wave of summer heat reaches from 50 to 100 feet. The line of uniform yearly temperature is from 57 to 99 feet below the surface (Forbes).

Not only does the amount of radiation differ in different soils, but a change is produced in the heat by the kind of soil. The remarkable researches of Tyndall have shown that the heat radiated from granite passes through aqueous vapour much more readily than the heat radiated by water (though the passage is much more obstructed than in dry air). In other words, the luminous heat rays of the sun pass freely through aqueous vapours and fall on water and granite; but the absorption produces a change in the heat, so that it issues again from water and granite changed in quality; it will be most important for physicians if other soils are found to produce analogous changes.

With regard to the effect of temperature of the soil on disease, it can hardly be doubted that it powerfully influences malaria, and probably also aids the progress of cholera.

Reflection of Light.—This is a matter of colour; the white glaring soils reflect light, and such soils are generally also hot, as the rays of heat are also reflected. The effect of glare on the eyes is obvious, and in the tropics this becomes a very important point. If a spot bare of vegetation, and with a white surface, must be used for habitations, some good result might be obtained by colouring the houses pale blue or green.

Chemical Composition of the Solid Parts of Soil.

Vegetable Matters.—Almost all soils contain vegetable matter. It exists in three chief forms—deposits, vegetable débris, and incrustations. Deposits occur in tracts of land which have been covered by silt brought down by floods, or which have been submerged by subsidence; forests have been thus buried, and again elevated. In the marshes of the Tuscan Maremma, and in many other cases, the vegetable forms can be traced without difficulty to a considerable depth, and the structure is even sometimes little changed, although so vast a period of time has elapsed. Vegetable débris produced by the decay of plants lies on, or is washed into, the soil, and in this way the ground may be penetrated to great depths. In some cases, especially in sandy plains at the foot of hills, the rain brings down very finely divided débris, and is filtered as it passes through the soil, so that each particle of sand becomes coated over or incrusted with a film of vegetable matter. If such a plain be subjected to alternate wettings and dryings, and to heat, the conditions of development of malaria may be present in great intensity; although there is not only no marsh, but the sand is to all appearance dry and pure.

Animal Matters.—The remains of animals are found in all but the oldest rocks; generally the animal constituents have disappeared, but it is remarkable how in some cases, even in geological formations as old as the Tertiary strata, some animal matter may be found. On the surface there is perhaps no soil which does not contain some animal matters derived from dead animals or excreta, although, except in special cases, the amount is small.

The soil of countries which have been long settled is, however, often highly impure in the neighbourhood of habitations from the refuse (animal and vegetable) which is thrown out. In some loose soils cess-pits used for fifty years have never been emptied, and are still not full, owing to soakage.[1] Pettenkofer conjectures that in Munich 90 per cent. of the excretions pass into the ground. In clayey soil there is, of course, much less infiltration than in sandy, and often scarcely any. In India the nitrification of vast tracts of land is for the most part owing to the oxidation of animal refuse.

A means of purification from animal impregnation has been, however, provided by oxidation and the influence of growing vegetation. In all soils, except the hottest and driest, animal refuse, under the influence of minute fermenting organisms, passes into ammonia, nitrites, nitrates, and fatty hydrocarbons rather rapidly, and these are eagerly absorbed by vegetation. A means is therefore pointed out which may keep the soil clear from dangerous animal impregnations, and this is no doubt one reason why improvement in public health follows improved cultivation. It has become quite clear that in the plans for the disposal of the human and animal excreta of towns, whether by wet or dry methods, an essential part of the plan is to submit these excreta to the influence of growing plants as soon as possible.

Mineral Matters.—An immense number of mineral substances are scattered through the crust of the earth, but some few are in great preponderance, viz., compounds of silicium, aluminum, calcium, iron, carbon, chlorine, phosphorus, potassium, and sodium.

In examining the constituents of the soil round any dwellings, the immediate local conditions are of more importance than the extended geological generalisations; it is, so to speak, the house and not the regional geology which is of use. Still the general geological conditions, as influencing conformation and the movement of water and air through and over the country, are of great importance.

1. *The Granitic, Metamorphic, and Trap Rocks.*—Sites on these formations are usually healthy; the slope is great, water runs off readily; the air is comparatively dry; vegetation is not excessive; marshes and malaria are comparatively infrequent, and few impurities pass into the drinking water.

When these rocks have been weathered and disintegrated, they are supposed to be unhealthy. Such soil is absorbent of water; and the disintegrated granite of Hong-Kong is said to be rapidly permeated by a *fungus*;[2] but evidence as to the effect of disintegrated granite or trap is really wanting.

In Brazil[3] the syenite becomes coated with a dark substance, and looks like plumbago, and the Indians believe this gives rise to "calentura," or fever. The dark granitoid or metamorphic trap or hornblendic rocks in Mysore are also said to cause periodic fevers; and iron hornblende especially was affirmed by Dr Heyne of Madras to be dangerous in this respect. But the observations of Richter[4] on similar rocks in Saxony, and the fact that stations on the lower spurs of the Himalayas on such rocks are quite healthy, negative Heyne's opinion.

2. *The Clay Slate.*—These rocks precisely resemble the granite and granitoid formations in their effect on health. They have usually much

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[1] Göttisheim in Basel (*Das unterirdische Basel*, 1868).
[2] *Ost. Asiens*, von C. Friedel, 1863.
[3] M'Williams on *Yellow Fever in Brazil*, p. 7.
[4] *Schmidt's Jahrbücher*, 1864, No. 5, p. 240.

slope; are very impermeable; vegetation is scanty; and nothing is added to air or to drinking water.

They are consequently healthy. Water, however, is often scarce; and, as in the granite districts, there are swollen brooks during rain, and dry water-courses at other times swelling rapidly after rains.

3. *The Limestone and Magnesian Limestone Rocks.*—These so far resemble the former that there is a good deal of slope and rapid passing off of water. Marshes, however, are more common, and may exist at great heights. In that case the marsh is probably fed with water from some of the large cavities, which, in the course of ages, become hollowed out in the limestone rocks by the carbonic acid of the rain, and form reservoirs of water.

The drinking water is hard, sparkling, and clear. Of the various kinds of limestone, the hard oolite is the best, and magnesian is the worst; and it is desirable not to put stations on magnesian limestone if it can be avoided.

4. *The Chalk.*—The chalk, when unmixed with clay and permeable, forms a very healthy soil. The air is pure, and the water, though charged with calcium carbonate, is clear, sparkling, and pleasant. Goitre is not nearly so common, nor apparently calculus, as in the limestone districts.

If the chalk be marly, it becomes impermeable, and is then often damp and cold. The lower parts of the chalk, which are underlaid by gault clay, and which also receive the drainage of the parts above, are often very malarious; and in America some of the most marshy districts are on the chalk.

5. *The Sandstones.*—The permeable sandstones are very healthy; both soil and air are dry; the drinking water is, however, sometimes impure, and may contain large quantities of chlorides, especially in the New Red Sandstone when rock salt abounds. If the sand be mixed with much clay, or if clay underlies a shallow sand-rock, the site is sometimes damp.

6. *Carboniferous Formations.*—The hard millstone grit formations are very healthy, and their conditions resemble those of granite. The drinking water is generally pure and fairly soft.

7. *Gravels* of any depth are always healthy, except when they are much below the general surface, and water rises through them. Gravel hillocks are the healthiest of all sites, and the water, which often flows out in springs near the base, being held up by underlying clay, is very pure.

8. *Sands.*—There are both healthy and unhealthy sands. The healthy are the pure sands, which contain no organic matter and are of considerable depth. The air is pure, and so is often the drinking water. Sometimes the drinking water contains enough iron to become hard, and even chalybeate. The unhealthy sands are those which, like the subsoil of the Landes, in south-west France, are composed of siliceous particles (and some iron) held together by a vegetable sediment.

In other cases sand is unhealthy, from underlying clay or laterite near the surface, or from being so placed that water rises through its permeable soil from higher levels. Water may then be found within 3 or 4 feet of the surface; and in this case the sand is unhealthy and often malarious. Impurities are retained in it, and effluvia traverse it.

In a third class of cases the sands are unhealthy because they contain soluble mineral matter. Many sands (as, for example, in the Punjab) contain much magnesium carbonate and lime salts, as well as salts of the alkalies. The drinking water may thus contain large quantities of sodium chloride, sodium carbonate, and even lime and magnesian salts and iron. Without examination of the water it is impossible to detect these points.

9. *Clay, Dense Marls, and Alluvial Soils generally.*—These are always to be regarded with suspicion. Water neither runs off nor runs through; the air is moist; marshes are common; the composition of the water varies, but it is often impure with lime and soda salts. In alluvial soils there are often alternations of thin strata of sand and sandy impermeable clay; much vegetable matter is often mixed with this, and air and water are both impure. Vast tracts of ground in Bengal and in the other parts of India, along the course of the great rivers (the Ganges, Brahmaputra, Indus, Nerbudda, Krishna, &c.), are made up of soils of this description, and some of the most important stations even up country, such as Cawnpore, are placed on such sites.

The deltas of great rivers present these alluvial characters in the highest degree, and should not be chosen for sites. If they must be taken, only the most thorough drainage can make them healthy. It is astonishing, however, what good can be effected by the drainage of even a small area, quite insufficient to affect the general atmosphere of the place; this shows that it is the local dampness and the effluvia which are the most hurtful.

10. *Cultivated Soils.*—Well-cultivated soils are often healthy, nor at present has it proved that the use of manure is hurtful. Irrigated lands, and especially rice fields, which not only give a great surface for evaporation, but also send up organic matter into the air, are hurtful. In Northern Italy, where there is a very perfect system of irrigation, the rice grounds are ordered to be kept 14 kilometres (= 8·7 miles) from the chief cities, 9 kilometres (= 5·6 miles) from the lesser cities and the forts, and 1 kilometre (= 1094 yards) from the small towns. In the rice countries of India this point should not be overlooked.

11. *Made Soils.*—The inequalities of ground which is to be built upon are filled up with whatever happens to be available. Very often the refuse of a town, the cinders or dust-heaps, after being raked over, and any saleable part being removed, are used for this purpose. In other cases chemical or factory refuse of some kind is employed. The soil under a house is thus often extremely impure. It appears, however,[1] that the organic matters in soil gradually disappear by oxidation and removal by rain, and thus a soil in time purifies itself. The length of time in which this occurs will necessarily depend on the amount of impurity, the freedom of access of air, and the ease with which water passes through the soil. In the soil at Liverpool, made from cinder refuse, vegetable matters disappeared in about three years; textile fabrics were, however, much more permanent; wood, straw, and cloth were rotten and partially decayed in three years, but had not entirely disappeared. In any made soil, it should be a condition that the transit of water through its outlet from the soil shall be unimpeded. The practice of filling up inequalities is certainly, in many cases, very objectionable, and should only be done under strict supervision.

SUB-SECTION III.

Malarious Soils.—Doubts have been expressed whether those paroxysmal fevers, which are curable by quinine, are produced either by telluric effluvia, or by substances passing from the soil into the drinking water.[2] The

[1] See Report on the *Health of Liverpool*, by Dr Burdon Sanderson and the late Dr Parkes, p. 9 *et seq.*

[2] On these questions see North, "Lectures on Malarial Fevers," *Brit. Med. Jour.*, April 23, 30, and May 7, 1887.

evidence, however, appears conclusive in favour of both these modes of entrance into the body.

If it be asked, What exact chemical conditions of soil favour the production of the malaria which causes periodical fevers? the answer cannot be given, because no great chemist has ever systematically prosecuted this inquiry, and, in fact, it may be said that, singularly enough, there are few good analyses of malarious soils, although no problem is perhaps more important to the human race. It seems pretty clear that the mineral constituents of the soil are of little or no consequence. Malaria will prevail on chalk, limestone, sand, and even, under special conditions, on granite soils. In all likelihood the agent will prove to be an organism, although up to the present time no decisive evidence has been obtained that would satisfactorily discriminate the organism.

The following soils have been known to cause the evolution of the agent causing periodical fevers in the malarious zone:—

1. *Marshes.*—Except those with peaty soils, those which are regularly overflowed by the sea (and not occasionally inundated), and the marshes in the southern hemisphere (Australia, New Zealand, New Caledonia), and some American marshes, which, from some as yet unknown condition, do not produce malaria.

The chemical characters of well-marked marshes are a large percentage of water, but no flooding; a large amount of organic matter (10 to 45 per cent.) with variable mineral constituents; silicates of aluminum; calcium, magnesium, and alkaline sulphates; calcium carbonate, &c. The surface is flat, with a slight drainage; vegetation is generally abundant.

The analyses of the worst malarious marshes show a large amount of vegetable organic matter. A marsh in Trinidad gave 35 per cent.; the middle layer in the Tuscan Maremma 30 per cent. The organic matter is made up of humic, ulmic, crenic, and apocrenic acids—all substances which require renewed investigation at the hands of chemists. Vegetable matter embedded in the soil decomposes very slowly; in the Tuscan Maremma, which must have existed many centuries, if not thousands of years, many of the plants are still undestroyed. The slow decomposition is much aided by heat, which makes the soil alkaline from ammonia (Angus Smith), and retarded by cold, which makes the ground acid, especially in the case of peaty soils.

It would now seem tolerably certain that the growing vegetation covering marshes has nothing to do with the development of malaria.

2. *Alluvial Soils.*—Many alluvial soils, especially, as pointed out by Wenzel,[1] those most recently formed, give out malaria, although they are not marshy. It is to be presumed that the newest alluvium contains more organic matters and salts than the older formations. Many alluvial soils have a flat surface, a bad outfall, and are in the vicinity of streams which may cause great variations in the level of the ground water. Mud banks also, on the side of large streams, especially if only occasionally covered with water, may be highly malarious; and this is the case also with deltas and old estuaries.

3. The soils of *Tropical Valleys, Ravines, Nullahs.*—In many cases large quantities of vegetable matter collect in valleys, and, if there is any narrowing at the outlet of the valley, the overflow of the rains may be impeded. Such valleys are often very malarious, and the air may drift up to the height of several hundred feet.

[1] Quoted by Hirsch, *Jahresb. für die Ges. Med.*, 1870, Band ii. p. 209.

4. *Sandy plains*, especially when situated at the *foot of tropical hills*, and covered with vegetation, as in the case of the "Terai" at the base of some parts of the Himalayan range. In other cases, the sandy plains are at a distance from hills, and are apparently dry, and not much subjected to the influence of variations in the ground water. The analysis of such sand has not yet been properly made, but two conditions seem of importance. Some sands, which to the eye appear quite free from organic admixture, contain much organic matter. Fauré has pointed out that the sandy soil of the Landes in south-west France contains a large amount of organic matter, which is slowly decomposing, and passes into both air and water, causing periodical fevers. This may reasonably be conjectured to be the case with other malarious sands. Then, under some sands, a few feet from the surface, there is clay, and the sand is moist from evaporation. Under a great heat a small quantity of organic matter may thus be kept in a state of change. This is especially the case along the dried beds of watercourses and torrents; there is always a subterranean stream, and the soil is impregnated with vegetable matter. In other cases the sands may be only malarious during rains, when the upper stratum is moist.

5. Certain *hard rocks* (*granitic* and *metamorphic*) have been already noticed (p. 15), especially when weathered, to have the reputation of being malarious; more evidence is required on this point. As Friedel justly remarks of Hong-Kong, it is not the disintegrated granite, *per se*, which causes the fever, but the soil of the woods and dells, and the clefts in the rocks, which were derived from the granite, and are soon filled with a cryptogamic vegetation.

The *magnesian limestone* rocks which have been subjected to volcanic action have also been supposed to be especially malarious (Kirk, who instances the rocks at Sukkar), but the evidence has not been yet corroborated.

6. *Iron Soils.*—Sir Ranald Martin has directed attention to the fact that many reputed malarious soils contain a large proportion of iron. No good evidence has been adduced that this is connected with malaria, but the point requires further examination. The red soil from Sierra Leone, which contains more than 30 per cent. of oxides of iron, shows nothing which appears likely to cause malaria.[1] The peroxide of iron is a strong oxidising agent, readily yielding oxygen to any oxidisable substance, and regaining oxygen from the air. It may, therefore, assist in the oxidation of vegetable matter in an iron soil.[2]

7. In certain cases attacks of paroxysmal fever have arisen from quite *localised* conditions unconnected with soil, which seem, however, to give some clue to the nature of the process which may go on in malarious ground.

Friedel[3] mentions that in the Marine Hospital at Swinemünde, near Stettin, a large day-ward was used for convalescents. As soon as any man had been in this ward for two or three days, he got a bad attack of tertian ague. In no other ward did this occur, and the origin of the fever was a

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[1] Analysis of the Red Earth of Sierra Leone, by Assistant-Surgeon J. A. B. Horton, M.D., *Army Medical Reports*, vol. viii. p. 333.

[2] The surface soil of the Gold Coast (Connor's Hill, Cape Coast Castle) has also been analysed by Mr J. H. Warden, F.C.S. (*Indian Medical Service*). It contained only 3·28 per cent. of ferric oxide and a trace of ferrous oxide; the organic matter was only 4·4 per cent. The surface soil is only eight inches thick, and below this is a stratum of a dark red colour, like burnt bricks, probably containing more iron. The sample above mentioned was brought home by Surgeon-Major J. Fleming, A.M.D.—*Army Medical Reports*, vol. xiv. p. 264.

[3] *Ost. Asiens*, Berlin, 1863, p. 338.

mystery, until, on close inspection, a large rain cask full of rotten leaves and brushwood was found; this had overflowed, and formed a stagnant marsh of 4 to 6 square feet close to the doors and windows of the room, which on account of the hot weather were kept open at night. The nature of the effluvium was not determined.

Dr Holden[1] relates an instance in which, on board a ship at sea, eight cases of ague occurred from the emanations of a large quantity of mould which had formed in some closed store-rooms, which were exposed to the bilge water.[2]

SECTION II.

EXAMINATION OF SOIL.

Mechanical Condition of Soil.—The degree of density, friability, and penetration by water should be determined both in the surface and subsoil. Deep holes, 6 to 12 feet, should be dug, and water poured on portions of the soil. Holes should be dug after rain, and the depth to which the rain has penetrated observed. In this way the amount of dryness, the water-level, and the permeability can be easily ascertained.

The surface or subsoil can also be mechanically analysed by taking a weighed quantity (100 grammes), drying it, and then picking out all the large stones and weighing them, passing through a sieve the fine particles, and finally separating the finest particles from the coarser by mixing with water, allowing the denser particles to subside, and pouring off the finer suspended particles. The weight of the large stones, plus the weight of the stones in the sieve and of the dried coarser particles, deducted from the total weight, gives the amount of the finely divided substance, which is probably silicate of aluminum.

Temperature.—The temperature at a depth of 2 or 3 feet, at two to four o'clock in the afternoon, would be an important point to determine in the tropics, and also the temperature in early morning. At present such observations, though very easily taken, and obviously very instructive, are seldom made, although a commencement in that direction was made in the investigations of Messrs Lewis and Cunningham at Calcutta.[3] It might also be useful to take a certain depth of soil, say 6 inches, and, placing a thermometer in it, determine the height of the thermometer on exposure to the sun's rays for a given time at a certain hour.

Chemical Examination.—The chemical constituents of soil are, of course, as numerous as the elements; more than 500 minerals have been actually named. But certain substances are very rare, and, for the physician, the chief constituents of soils are the following substances or combinations:—Silica, alumina, lime, iron, magnesia, chlorine, carbonic acid, phosphoric acid, sulphuric acid, nitric acid. A few simple tests are often very useful, if we are uncertain what kind of rock we have to deal with. Few persons could mistake granite, trap, gneiss, or rocks of that class, or clay-slate or crystalline limestone. But fine white sandstones, or freestone, or even fine millstone grit, might be confounded with lime rocks, or magnesian lime-

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[1] *American Journal of Med. Science*, January 1866.

[2] Staff-Surgeon P. Mansfield, R.N., recounts an outbreak of yellow remittent fever on board ship at Rio, coincident with the growth of an enormous quantity of gigantic fungus in the hold. It seems unlikely, however, that this was more than a coincidence.

[3] *Op. cit.*

stone. A few drops of hydrochloric acid will often settle the question, as it causes effervescence in the calcium carbonate and magnesian rocks.[1]

A more complete examination should include the following points :—

1. *Percentage of Water.*—Take 10 grammes of a fair sample of soil, and dry at a heat of 220° F. (104°·5 C.); weigh again; the difference is water or volatile substance.

2. *Percentage of Volatile Matters (including Water), destroyed by Incineration.*—Take another weighed portion of soil, and incinerate at a full red heat; recarbonate with carbonic acid solution, or with ammonium carbonate; heat to expel excess of ammonia; dry and weigh.

3. *Absorption of Water.*—Place the dried soil in a still atmosphere, on a plate in a thin layer, and reweigh in twenty-four hours; the increase is the

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[1] It may be useful to give (from Page's *Handbook of Geological Terms*) a few compositions, and to define a few of the common mineralogical words used in geology :—

Quartz.—Crystallised silica.
Felspar.—Silica, alumina (aluminum trisilicate), potash, or soda, and a little lime, magnesia, and ferric oxide, crystallised or amorphous.
Mica.—Silica, alumina, ferric oxide, and potash, or magnesia, or lime, or lithia.
Chlorite.—Mica, but with less silica and more magnesia and iron.
Granite.—Composed of quartz, felspar, and mica.
Syenite.—Same as granite, but with hornblende instead of mica.
Syenitic Granite.—Quartz, felspar, mica, and hornblende.
Gneiss.—Same elements as granite, but the crystals of quartz and felspar are broken and indistinct.
Hornblende.—A mineral entering largely into granite and trappean rocks, composed of silica (47 to 60), magnesia (14 to 28), lime (7 to 14), with a little alumina, fluorine, and ferrous oxide.
Augite.—Like hornblende, only less silica (does not resist acids).
Hypersthene.—Like augite, only with very little lime; it contains silica, magnesia, and iron; resists acids.
Greenstone.—Hard granular crystalline varieties of trap, felspar, and hornblende, or felspar and augite.
Basalt.—Augite and felspar, olivine, iron pyrites, &c.
Trap.—Tabular greenstone and basalt.
Schist.—A term applied to the rocks mentioned above, when they are foliated or split up into irregular plates.
Clay-Slate.—Argillaceous arenaceous rocks, with more or less marked cleavage.
Limestone.—All varieties of hard rocks, consisting chiefly of calcium carbonate.
Oolite.—Limestone made up of small rounded grains, compact or crystalline, like the roe of a fish.
Chalk.—Soft calcium carbonate.
Magnesian Limestone.—Any limestone containing 20 per cent. of a salt of magnesia, frequently not crystallised.
Dolomite.—Crystallised magnesian limestone.
Kunkar.—A term used in India to denote nodular masses of impure calcium carbonate.
Gypsum—Selenite.—Calcium sulphate.
Gravel.—Water-worn and rounded fragments of any rock, chiefly quartz; size, from a pea to a hen's egg.
Sand.—Same, only particles less than a pea.
Sandstone.—Consolidated sand; the particles held together often by lime, clay, and ferric oxide.
Freestone.—Any rock which can be cut readily by the builder; usually applied to sandstone.
Millstone Grit.—Hard gritty sandstone of the carboniferous series, used for millstones. Grit is the term generally used when the particles are larger and sharper than in ordinary sandstone.
Clay.—Aluminum silicate.
Greensand.—Lower portion of the chalk system in England; sand coloured by chloritous iron silicate.
Marl.—Lime and clay.
Laterite.—A term much used in India to denote a more or less clayey stratum which underlies much of the sand in Bengal, some parts of Burmah, Bombay presidency, &c.
Conglomerate.—Rocks composed of consolidated gravels (*i.e.*, the fragments water-worn and rounded).
Breccia.—Rocks composed of *angular* (not water-worn) fragments (volcanic breccia, osseous breccia, calcareous breccia).
Shale.—A term applied to all clayey or sandy formations with lamination; it is often consolidated and hardened mud.

absorbed water. An equal portion of pure sand should be treated in the same way as a standard. It would be well to note the humidity of the air at the time.

4. *Power of holding Water.*—Thoroughly wet 100 grammes, drain off water as far as possible, and weigh; the experiment is, however, not precise.

5. *Substances taken up by Water.*—This is important, as indicating whether drinking water is likely to become contaminated. Rub thoroughly 10 grammes in pure cold water, filter, and test for organic matter by chloride of gold, or by evaporation and careful incineration; test also for chlorine, sulphuric acid, lime, alumina, iron, nitric acid.

6. *Substances taken up by Hydrochloric Acid.*—While water takes up alkaline chlorides and sulphates, nitrates, &c., the greater part of the lime, magnesia, and alumina is left undissolved. The quantity can be best determined by solution in pure hydrochloric acid.

(*a*) To 40 grammes of the soil add 30 c.c. of pure hydrochloric acid, and heat; note effervescence. Add about 100 c.c. of water. Digest for twelve hours. Dry and weigh the undissolved portion.

(*b*) To the acid solution add ammonia. Alumina and oxide of iron are thrown down. Dry and weigh precipitate.

(*c*) To the solution filtered from (*b*) add ammonium oxalate. Dry; wash and burn the calcium oxalate. Weigh as carbonate.

(*d*) To the solution filtered from (*c*) add sodium phosphate. Collect; dry and weigh (100 parts of the precipitate = 79 parts of magnesium carbonate); or determine as pyrophosphate.

The portion insoluble in hydrochloric acid consists of quartz, clay, and silicates of aluminum, iron, calcium, and magnesium. If it is wished to examine it further, it should be fused with three times its weight of sodium carbonate, then heated with dilute hydrochloric acid. The residue is silica. The solution may contain iron, lime, magnesia, and alumina. Test as above.

7. *Iron.*—Iron can be determined by the potassium dichromate, or by the permanganate. As the latter solution is used for other purposes, it is convenient to employ it in this case.

Dissolve 10 grammes of the soil in pure hydrochloric acid free from iron by aid of heat.

Add a little pure zinc, and heat to convert ferric into ferrous salts. Pour off the solution from the zinc that is still undissolved, and determine iron by potassium permanganate; *i.e.*, heat to 140° F. (60° C.) and then drop in the solution of permanganate till a permanent but slightly pink colour is given. 1 c.c. = 0·7 milligramme of pure iron.[1] Or the colour test may be used, as explained under ALUM IN BREAD.

Microscopic Examination.—Attention must now be paid to this, although it has not hitherto been much studied. *Bacteria* of various kinds have been found, and they have been observed to be more numerous in the most impure and unhealthy soils, as might have been anticipated. Some forms, however, are beneficial, as it is under their influence that the oxidation (nitrification) of nitrogenous organic matter is carried on. Either samples of the soil itself may be examined, or the air may be drawn out of the soil at different depths, by means of an aspirator, and passed over nutrient media for cultivations.

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[1] See Appendix A.

SECTION III.

METHOD OF EXAMINING A LOCALITY FOR MILITARY PURPOSES.

A place should be seen at all times of the year, in the wet as well as in the dry seasons, in the autumn and winter as well as in the spring, and at night as well as by day. The following order will be found a convenient one :—

1. *Conformation.*—Height above sea-level and elevation of hills above the plain. (Determine by mercurial barometer or aneroid, or, if possible, get the heights from an engineer.) Angle of declivity of hills; amount of hill and plain; number, course, and characters of valleys and ravines in hills; dip of strata; geological formation; watersheds and courses; exposure to winds; situation, amount and character of winds; sunlight, amount and duration; rain, amount and frequency; dust.

2. *Composition.*—Mineralogical characters. Presence of animal or vegetable substances; amount and characters.

3. *Covering of soil* by trees, brushwood, grass, &c.

4. *Points for special Examination.*—Amount of air; of moisture. Height of subsoil water, at the wettest and driest seasons. Changes in level, and rapidity of change of subsoil or ground water. Direction of subsoil current. Condition of vegetable constituents; examination of substances taken up by water, &c.

Such a complete examination demands time and apparatus, but it is quite necessary.

A fair opinion can then be formed; but if a large permanent station is to be erected, it is always desirable to recommend that a temporary station should be put up for a year, and an intelligent officer should be selected to observe the effect on health, to take meteorological observations, and to examine the water at different times of the year. Sometimes a spot more eligible than that originally chosen may be found within a short distance, and the officer should be instructed to keep this point in view.

The medical officer has nothing to do with military considerations or questions of supply, but, if he is able to suggest anything for the information of the authorities, he should of course do so.

The opinion of Lind, whose large experience probably surpassed that of his contemporaries, and of our own time, should be remembered:—"The most healthy countries in the world contain spots of ground where strangers are subject to sickness. There is hardly to be found any large extent of continent, or even any island, that does not contain some places where Europeans may enjoy an uninterrupted state of health during all seasons of the year."[1]

In choosing a site for a temporary camp, so elaborate an examination is not possible. But as far as possible the same rules should be attended to. There is, however, one difference—in a permanent station water can be brought from some distance; in a temporary station the water-supply must be near at hand, and something must be given up for this.[2] The banks of rivers, if not marshy, may be chosen, care being taken to assign proper spots for watering, washing, &c. A river with marshy banks must never be chosen in any climate, except for the most imperative military reasons; it is better to have the extra labour of carrying water from a distance.

A site under trees is good in hot countries, but brushwood must be avoided.

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[1] Lind, *Diseases of Europeans in Hot Climates*, 4th edition, p. 200.

[2] See remarks on this point, in the *Regulations and Instructions for Encampments*, p. 2.

SECTION IV.

PREPARATION OF SITE FOR MILITARY PURPOSES.

In any locality intended to be permanently used, the ground should be drained with pipe drains. Even in the driest of the loose soils this is desirable, especially in hot climates, where the rainfall is heavy. In impermeable rocky districts it is less necessary. The size, depth, and distance of the drains will be for the engineer to determine; but generally deep drains (4 to 8 feet in depth, and 12 to 18 feet apart) are the best. If there is no good fall, it has been proposed to drain into deep pits; but usually an engineer will get a fall without such an expedient. A good outfall, however, should be a point always looked to in choosing a station. These drains are intended to carry off subsoil water, and not surface water. This latter should be provided for by shallow drains along the natural outfalls and valleys. As far as drainage is concerned, we have then to provide for mere surface water, and for the water which passes below the surface into the soil and subsoil.

Brushwood should usually be cleared away, but trees left until time is given for consideration. In clearing away brushwood, the ground in the tropics should be disturbed as little as possible; and if it can be done, all cleared spots should be soon sown with grass. Brushwood should not be removed from a marsh.

In erecting the buildings, the ground should be excavated as little as possible; in the tropics especially hills should never be cut away. The surface should be levelled, holes filled in, and those portions of the surface, on which rain can fall from buildings, well paved, with good side gutters. This is especially necessary in the tropics, where it is of importance to prevent the ground under buildings from becoming damp; but the same principles apply everywhere.

In a temporary camp so much cannot be done; but even here it is desirable to trench and drain as much as possible. It not unfrequently happens in war that a camp intended to stand for two or three days is kept up for two or three weeks, or even months. As soon as it is clear that the occupation is to be at all prolonged, the same plans should be adopted as in permanent stations.

The great point is to carry off water rapidly, and it is astonishing what a few well-planned surface drains will do.

The rules for improving the healthiness of a site may be thus summarised:—

1. Drain subsoil and lower the level of the ground water.
2. Pave under houses, so as to prevent the air from rising from the ground.
3. Pave or cover with short grass all ground near buildings in malarious districts.
4. Keep the soil from the penetration of impurities of all kinds by proper arrangements for carrying away rain, surface, and house water and house impurities.

CHAPTER II.

WATER.

THE supply of wholesome water in sufficient quantity is a fundamental sanitary necessity. Without it injury to health inevitably arises, either simply from deficiency of quantity, or more frequently from the presence of impurities. In all sanitary investigations, the question of the water-supply is one of the first points of inquiry, and of late years much evidence has been obtained of the frequency with which diseases are introduced by the agency of water. In such an investigation, if the headings of the sub-sections of this chapter are followed, and the facts are noted under each heading in order, it will be hardly possible to overlook any condition which may have affected health. The order of investigation would be as follows:—Quantity of water per head; how it is collected, stored, distributed; what is its composition; is it wholesome water at its source and throughout, or has it been contaminated at any point of its distribution; what are the effects presumed to arise from it?[1]

SECTION I.

ON THE QUANTITY AND SUPPLY OF WATER.

SUB-SECTION I.—1. QUANTITY OF WATER FOR HEALTHY MEN.

In estimating the quantity of water required daily for each person, it is necessary to allow a liberal supply. There should be economy and avoidance

[1] *Army Regulations on the subject of Water.*—The "Regulations for the Medical Department of Her Majesty's Army" (*Army Regulations*, vol. vi., 1885), frequently refer to the supply of water. In Part I. Section iii. paragraph 33 (*d*), the Surgeons-General and Deputy Surgeons-General are directed to "ascertain that the water-supply is good and abundant, and perfectly protected from pollution." Also paragraph 33 (*c*), "that the means of ablution and cleanliness are sufficient and made use of by the men." As regards hospitals they are also to ascertain (paragraph 39), "that the water-supply is pure and abundant and sufficient for all the requirements of a hospital, ... and that the lavatories, bath-rooms, and water-closets are kept in proper order." In the Sanitary Regulations, Part VI. Section ii. paragraph 1048, the medical officer in charge of troops is ordered to examine, from time to time, "the quality and amount of drinking-water," and to ascertain "whether wells and other supplies of water are protected from soakage from latrines, cesspools, drains, or other sources of impurity." He is also ordered to inspect the lavatories and baths. In Sections iv., vi., and vii., paragraphs 1068, 1104, 1114, the same supervision over the water-supply of hospitals, camps, garrisons, and transport ships is enjoined

When an army takes the field a Sanitary Officer is appointed, and he examines into all sanitary points, including the water-supply (Section viii. paragraphs 1126, 1134, 1138). Filters are also to be inspected (Part VI. Section iv. paragraphs 1075, 1076.)

In the quarterly and annual reports the water-supply has to be considered, in common with other sanitary conditions, including "the sources, quality, and quantity of the water-supply, and whether it is wholesome, and what means of purification are in use, if such be necessary." Also, "Baths and lavatories, their condition, and if sufficient for cleanliness of troops and sick; whether there are bathing parades, and how often a week." Also to report on "Bad water, especially if any organic impurity exists" (Appendix No. 6).

In the "Instructions in case of an Invasion of Cholera" (Appendix No. 5, paragraph 11), special attention is directed to the water-supply. Provision is also made for the chemical examination of water when required (Part VI. Section vi. paragraph 1107, and Appendix No. 8).

of waste; but still, any error in supply had far better be on the side of excess. In England many poor families, either from the difficulty of obtaining water or of getting rid of it, or from the habits of uncleanliness thus handed down from father to son, use an extremely small amount. It would be quite incorrect to take this amount as the standard for the community at large, or even to fix the smallest quantity which will just suffice for moderate cleanliness. It is almost impossible to give a definition of cleanliness, nor perhaps is it necessary, since there is a general understanding of what is meant.

It must be clearly understood for what purposes water is supplied. It may be required for drinking, cooking, and ablution of persons, clothes, utensils, and houses; for cleansing of closets, sewers, and streets; for the drinking and washing of animals, washing of carriages and stables; for trade purposes; for extinguishing fires; for public fountains or baths, &c.

In towns supplied by water companies, the usual mode of reckoning is to divide the total daily supply in gallons by the total population, and to express the amount per head per diem.

Thus in 1884 the total population of the metropolis and suburbs was reckoned at 4,944,553, and the water supplied daily by all the eight companies was 139,805,082 gallons, or 22,433,516 cubic feet. This gives 28·3 gallons or 4½ cubic feet per head. Of the total amount, 110,000,000 gallons are from the Thames (restricted to that amount); the rest, that is, the New River, East London, and Kent, are from the River Lea and from wells, the quantity being unrestricted.

The following are some of the gross amounts used at the present time for all the above purposes, as judged of in this way:—

	Gallons per head of population daily.
New River Company in London, 1884,[1] . .	25·0
East London Water-Work Company, ,, . .	31·5
Kent ,, ,, ,, . .	26·6
Chelsea ,, ,, ,, . .	37·0
West Middlesex ,, ,, ,, . .	26·7
Grand Junction ,, ,, ,, . .	32·3
Southwark and Vauxhall ,, ,, . .	26·5
Lambeth ,, ,, ,, . .	26·5
Average of London Districts, .	28·3
Southampton, ...	35
Glasgow, ...	50
Edinburgh, ...	35
Liverpool, ...	30
Sheffield, ...	20
Paris, ...	31
Calcutta (for Europeans),[2] amount originally intended,	30 ?
,, (for Natives), ,, ,, ,,	15 ?
New York,[3]	83

[1] These and other London amounts are taken from Colonel Sir Francis Bolton's Handbook on London Water Supply, International Health Exhibition, 1884. See for former amounts the *Report of the Select Committee of the House of Commons on London Water Supply*, 1880.

[2] The daily supply in Calcutta was, in 1871, 5,000,000 gallons of filtered water; in 1879 it was 7¼ millions and 1 million gallons unfiltered for watering roads. This, however, after all deductions, only left 3 gallons per head for domestic purposes. A new scheme is in progress which will provide 8,000,000 more daily, thus securing 12 gallons per head.

[3] In former editions this was stated at 300, but it is given as 100 (?) in Buck's *Hygiene and Public Health*. These are, however, U.S. gallons, equal to 83 imperial gallons.

In 1857 the average supply to fourteen English towns, of second-rate magnitude, was 24 gallons. The average of 72 English and Scotch towns, supplied on the constant system, is 134·4 gallons per house (but this includes the supply to factories, of which there were 16,087 to 889,028 houses), or (at 5 persons to each house), 26·7 per head; of 23 towns, supplied on the intermittent system, 127 per house, 25·4 per head, including 1367 factories to 137,414 houses; and of London, also on the intermittent system, 204, or 41 per head, including 5340 factories to 499,582 houses.[1] The range in individual cases is, however, very great, from 25 gallons per house (5 per head) in one small town to 700 at Middlesborough (140 per head). Mr Bateman has stated that in the manufacturing towns of Lancashire and Yorkshire the amount was from 16 to 21 gallons, in some cases less.[2]

At Norwich about 14½ gallons daily per head are supplied on the constant system, of which 10·5 are taken for domestic purposes, 3 for trade, and ·7 gallons for public and sanitary purposes.[3] In Manchester the supply is also constant, and is 14 gallons per head for domestic, and 7 for trade purposes. In 1878 in 15 American cities the supply was on the average 55 gallons per head.[4]

By decision of the Secretary of State for War, a soldier receives 15 gallons daily; no extra allowance is made for the wives and children in a regiment.

The gross amount thus taken is used for different purposes, which must now be considered.

Amount for Domestic Purposes, excluding Water-Closets.

This item includes drinking, cooking, washing the person, the clothes, the house utensils, and the house.

An adult requires daily about 70 to 100 ounces (3½ to 5 pints) of water for nutrition; but about 20 to 30 ounces of this are contained in the bread, meat, &c., of his food, and the remainder is taken in some form of liquid. There are, however, wide ranges from the average. Women drink rather less than men; children drink, of course, absolutely less, but more in proportion to their bulk than adults. The rules for transport vessels allow 8 pints in, and 6 out of the tropics for cooking and drinking. During hot weather and great exertion a man will, of course, drink much more.

In some experiments made for the War Office in 1866, at the Richmond Barracks in Dublin and the Anglesea Barracks in Portsmouth, the amount of the different items of the domestic supply (excluding latrines, which take 5 gallons per head) is thus given :—

	Gallons per soldier daily.
Cook-house,	1
Ablution rooms and baths,	4
Cleaning barracks,	2·25
Wash-house and married people,	2·5
	9·75

[1] *Sixth Report of the Rivers Pollution Commissioners*, pp. 232, 233.

[2] See table in the *Sixth Report of the Rivers Pollution Commissioners.*

[3] Report by Dr Pole, F.R.S. Enormous saving was accomplished by taking steps to prevent waste.

[4] Dr F. H. Brown, in Buck's *Hygiene*, vol. i. p. 180. A table is also given by Prof. W. R. Nichols (p. 212) showing the supply to 18 cities, ranging from 20 imperial gallons in Louisville to 116 in Washington.

Dr Parkes measured the water expended in several cases; the following was the amount used by a man in the middle class, who may be taken as a fair type of a cleanly man belonging to a fairly clean household:—

	Gallons daily per one person.
Cooking, ...	.75
Fluids as drink (water, tea, coffee), ...	·33
Ablution, including a daily sponge-bath, which took $2\frac{1}{2}$ to 3 gals.,	5
Share of utensil and house-washing, ...	3
Share of clothes (laundry) washing, estimated, . .	3
	12

These results are tolerably accordant with the Dublin experiments, if we remember that with a large household there is economy of water in washing utensils and clothes, and that the number of wives and children in a regiment is not great. In poor families, who draw water from wells, the amount has been found to vary from 2 to 4 gallons per head, but then there was certainly not perfect cleanliness.

Mr Bateman[1] states that, in a group of cottages with 82 inmates, the daily average amount was $7\frac{1}{2}$ gallons per head, and in another group 5 gallons per head. Dr Letheby found in the poor houses in the city of London the amount to be 5 gallons.[2] In experiments in model lodging-houses, Mr Muir states that 7 gallons daily were used.[3] Mr Easton, in his own house in London, found he used about 12 gallons per head, of which about 5 were for closets, leaving 7 for other uses; but probably the laundry washing was not included. In the convict prison at Portsmouth, where there are water-closets, and each prisoner has a general bath once a week, the amount is 11 gallons (Wilson).

In several of the instances just referred to, it may be questioned whether the amount of cleanliness was equal to what would be expected in the higher ranks. In most instances quoted no general baths were used; but it is now becoming so common in England to have bath-rooms that they are often put even in eight-roomed houses. A general bath for an adult requires, with the smallest adult bath (*i.e.*, only 4 feet long and 1 foot 9 inches wide), 38 gallons, and many baths will contain 50 to 60 gallons. A good shower-bath will deliver 3 to 6 gallons. General baths used only once a week will add 5 or 6 gallons per head to the daily consumption.

We may safely estimate that for personal and domestic use, without baths, 12 gallons per head daily should be given as a usual minimum supply; and with baths and perfect cleanliness, 16 gallons should be allowed. This makes no allowance for water-closets or for unavoidable waste. If from want of supply the amount of water must be limited, 4 gallons daily per head for adults is probably the least amount which ought to be used, and in this case there could not be daily washing of the whole body, and there must be insufficient change of underclothing.

If public baths are used the amount must be greatly increased. The largest baths the world has seen, those of Ancient Rome, demanded a supply of water so great as, according to Leslie's calculations, to raise the daily average per head to at least 300 gallons.

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1 *On Constant Water Supply*, by Messrs Bateman, Beggs, and Rendle. 1867.
2 *Report of the East London Water Bill Committee*, 1867, Questions 2346 and 2347.
3 *Ibid.*, p. 5.

Amount for Water-Closets.

The common arrangements with cisterns allow any quantity of water to be poured down, and many engineers consider that the chief waste of water is owing to water-closets. In some districts, by attention to this point, the consumption has been greatly reduced; in one case from 30 to 18, and in another from 20 to 12 gallons per head. It has not yet been precisely determined what quantity should be allowed for water-closets. Small cisterns, termed water-waste preventers, are usually put up in towns with constant water-supply, which give only a certain limited amount each time the closet is used. The usual size now in use holds about 2 gallons; but even 2 gallons are often insufficient to keep the pan and soil-pipe perfectly clean. This depends a good deal upon the kind of closet used. The water-waste preventer must be sometimes allowed to fill again, and be again emptied. Considering also that some persons will use the closet twice daily and sometimes oftener, and that occasionally more water must be used for thoroughly flushing the pan and soil-pipe, 6 gallons a day per head should probably be allowed for closets. In this particular instance a false economy in the use of water is most undesirable. Water latrines require less; the amount is not precisely known; the experiments of the Royal Engineers at Dublin give an average of 5 gallons per head, but it is considered this might be reduced.

In fixing the above quantities, viz., 12 gallons per head for all domestic purposes except general baths and closets, 4 gallons additional for general baths, and 6 for water-closets, endeavours have been made to base them upon facts, and they are probably not much in error. It is, however, necessary to make some allowance for unavoidable waste within the premises, and for extra supply to closets, and it will be a moderate estimate to allow 3 gallons daily per head for this purpose. This will make 25 gallons.

There is another reason for believing that an amount of about 25 gallons per head should pass from every house daily into sewers, if sewers are used. It is that in most cases this quantity seems necessary to keep the sewers perfectly clear, though in some cases, no doubt, with a well-arranged and constructed sewerage, a less amount may suffice. But the complete clearage of sewers is a matter of such fundamental importance that it is necessary to take the safest course. Hitherto much water has run merely to waste.

Amount for Animals.

From experiments conducted in some cavalry stables in 1866, by the Royal Engineers, the War Office authorities have fixed the daily supply for cavalry horses at 8 gallons, and for artillery horses at 10 gallons per horse. This is to include washing horses and carriages. The amount seems rather small. Of course the amount that horses drink varies as much as in the case of men, and depends on food, weather, and exertion; but if a horse is allowed free access to water at all times, and this should be the case, he will drink on an average 6 to 10 gallons, and at times more. In the month of October, with cool weather, a horse 16 hands high, doing 8 miles a day carriage work, and fed on corn and hay, was found to drink $7\frac{1}{2}$ gallons. Another carriage horse drank nearly the same amount. In a stable of cavalry horses doing very little work, and at a cool time of the year, the amount per horse was found to be $6\frac{1}{2}$ gallons. Taking a horse as weighing 1000 ℔ avoir., this is just an ounce of water per ℔ weight of horse. The amount used for washing was 3 gallons daily. In hot and dirty weather tho quantity for both

purposes would be larger. For washing a horse requires at least $1\frac{1}{2}$ gallons, and twice this amount if he is washed twice a day. There is a saving, however, if grooms wash several horses in the same water. It is difficult to say how much is used for carriage washing. On the whole, including carriage washing, &c., 16 gallons per horse is not an excessive amount. A cow or an ox, on dry food, will drink 6 or 8 gallons; a sheep or pig, $\frac{1}{2}$ to 1 gallon. In the Abyssinian expedition, the following was the calculation for the daily expenditure of water per head on shipboard:—

Elephants,	25 gallons.
Camels,	10 ,,
Oxen (large draught),	6 ,,
Oxen (small pack animals),	5 ,,
Horses,	6 ,,
Mules and ponies,	5 ,,

For 20 elephants and 100 men, 50,000 gallons were put on board for a voyage of 60 days.[1] F. Smith found, from experiments in India, that a horse in the month of February consumed on an average $8\frac{1}{2}$ gallons daily; this accords with Dr Parkes's experiments at home; of course, in hot weather the amount would be greater.[2]

Amounts required for Municipal and Trade Purposes.

For municipal purposes water is taken for washing and watering streets, for fountains, for extinguishing fires, &c. The amount for these and for trade purposes will vary greatly. Professor Rankine,[3] who gives an average allowance of 10 gallons per head for domestic purposes, proposes 10 more for trade and town use in non-manufacturing towns, and another 10 gallons in manufacturing towns. Considering, however, the comparatively small number of horses and cows in towns as compared with the human population, and the frequent rains in this country, which lessen watering of streets, the two latter quantities might, perhaps, in most cases be halved.

If, now, the total daily amount for all purposes be stated per head of population, it will be as follows:—

	Gallons.
Domestic supply (without baths or closets),	12
Add for general baths,	4
Water-closets,	6
Unavoidable waste,	3[4]
Total house supply,	25
Town and trade purposes, animals in non-manufacturing towns,	5[5]
Add for exceptional manufacturing towns,	5
	35

[1] This information was derived from Major Holland, Assistant Quartermaster-General, Abyssinian army.

[2] *A Manual of Veterinary Hygiene*, by Fred Smith, M.R.C.V.S., p. 2, London, Baillière, 1887.

[3] *Civil Engineering*, 1862, p. 731.

[4] Most engineers reckon the waste much higher than this; there is no doubt much room for economy in this matter. The greatest waste appears to be in transit before reaching the houses.

[5] This allowance will vary in every case, and must be very uncertain. In the London district 18 per cent. is reckoned for trade purposes.

In India and hot countries generally, the amounts now laid down would have to be altered. Much more must be allowed for bathing and for washing generally, while a fresh demand would arise for water to cool mats, punkahs, or air-passages by evaporation. In Calcutta it was intended to supply to Europeans 30 gallons per head and to natives 15 gallons daily,[1] but the amount has been really much less up to the present time.

In Madras it was assumed that the ultimate amount used would be 20 gallons per head, including all residents.[2] At present (in 1879) the total supply is about $2\frac{1}{2}$ millions daily; this in a population of about 400,000 would give $6\frac{1}{4}$ gallons per head. As yet, however, all the population do not use it.

2. Amount required for Sick Men.

In hospitals a much larger quantity must be provided, as there is so much more washing and bathing. From 40 to 50 gallons per head are often used. There are no good experiments as to the items of the consumption, but the following is probably near the truth :—

	Gallons daily.
For drinking and cooking, washing kitchen and utensils,	2 to 4
For personal washing and general baths,	18 to 20
For laundry washing,	5 to 6
Washing hospital, utensils, &c.,	3 to 6
Water-closets,	10 to 15
	38 to 51

It would be very desirable to have more precise data; possibly the amount for closets is put too high, but not greatly so when all cases are taken into account.

At Netley the amount per head per diem is put approximatively at 56 gallons (Major Nixon, R.E.). At Haslar (R.N.) the quantity is the same. At the Cambridge Hospital, Aldershot, the average is 160; Herbert Hospital, Woolwich, 89. In some of the Metropolitan hospitals there is singular diversity in the quantities. The London Hospital expends 62 gallons per head per diem, but they have a laundry on the premises; St Thomas's (no laundry), no less than 99; St Bartholomew's (no laundry), 40 gallons; whereas at Guy's, where there is a laundry, but where special care is taken to check unnecessary waste, only 20 are used. In Glasgow the amounts are: Royal Infirmary, 147 gallons; Western Infirmary, 119; Sick Children's, 55; Belvidere (infectious diseases), 97, daily. At the Edinburgh Royal Infirmary water is supplied free by Act of Parliament, and no note is taken of delivery or consumption.

Sub-Section II.—Collection, Storage, and Distribution of Water.

The daily necessary quantity of water per head being determined, the next points are to collect, store, and distribute it.

1. Collection.

In many cases collections of water occur naturally in the depressions of the surface, or the commingling of small streams forms rivers. The

[1] Gordon's *Army Hygiene*, p. 426.
[2] Captain Tulloch's *Report on the Drainage of Madras*, 1865, p. 93.

collection by men consists almost entirely in imitating these natural processes, and in directing to, and finally arresting at some point, the rain or the streamlets formed by the rain. The arrangements necessarily differ in each case. Rain-water is collected from roofs, or occasionally from pavements and flags, or cemented ground; in hilly countries, with deep ravines, a reservoir is sometimes formed by carrying a wall across a valley which is well placed for receiving the tributary waters of the adjacent hills, or on a flatter surface trenches may be arranged, leading finally to an excavated tank.

The collection of the surface water which has not penetrated is usually aimed at, but it has been proposed by Mr Bailey-Denton[1] to collect the subsoil water by drainage pipes, and thus to accomplish two objects—to dry the land, and to use the water taken out of it. Below the surface the water is collected by wells—shallow, deep, and Artesian,—or by boring.

With respect to wells, if they are situated near a river, and do not produce sufficient water, it has been recommended to lay perforated earthenware pipes parallel to the river, and below its fine-weather level, in trenches not less than 6 feet deep, and filled up above the pipes with fine gravel. The pipes end in the well, and water passing from the river and filtered through the gravel passes into them. The American tube-well (Norton's patent) is a very useful invention. It is merely a small iron pipe driven into the ground in lengths by means of a "monkey"; the water passes through small holes in the lowest part of the pipe, and is drawn up by a common or double action pump according to the depth.[2]

All these matters fall within the province of the engineer, and the medical part of the question is chiefly restricted to the consideration of the purity of the water. The cleanliness and nature of the surface (lead, zinc, copper, &c.) on which rain falls; the kind of ground and of cultivation; the amount of manuring; the nature of the subsoil if drainage water is used, and points of the like kind, have to be considered and supplemented by a chemical examination.

Rain.—The *amount* of water given by rain can be easily calculated, if two points are known, viz., the amount of rainfall and the area of the receiving surface. The rainfall can only be determined by a rain-gauge (the mode of constructing which is given in the chapter on PRACTICAL METEOROLOGY); the area of the receiving surface must be measured.

Supposing that it be known that the rainfall amounts to 24 inches per annum, and the area of the receiving surface (say the roof of a house) is 500 square feet;—

Multiply the area by 144 (number of square inches in 1 square foot) to bring it into square inches, and multiply this by the rainfall. The product gives the number of cubic inches of rain which fall on the house-top in a year, or in any time the rainfall of which is known. This number, if divided by 277·274, or multiplied by ·003607, will give the number of gallons which the roof of the house will receive in a year (viz., in this case 6232 gallons); or, if it is wished to express it in cubic feet, the number of cubic inches must be divided by 1728 (number of cubic inches in a cubic foot) or multiplied by ·00058. The calculation may be much simplified by multiplying the area of receiving surface by the rainfall in inches, and then by 0·52, thus: $500 \times 24 \times \cdot 52 = 6240$ gallons, or, still more simply,

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1 *On the Supply of Water to Villages and Farms*, by Mr Bailey-Denton, C.E.,

2 In the Ashantee Expedition the tube-well did not succeed, as it got clogged with sand (see Sir A. D. Home's Report, *Army Medical Reports*, vol. xv. p. 247).

multiply the area by half the rainfall, thus: $500 \times 12 = 6000$ gallons; here the error is only about 4 per cent.

To calculate the receiving surface of the roof of a house, we must not take into account the slope of the roof, but merely ascertain the area of the flat space actually covered by the roof. The joint areas of the ground-floor rooms will be something less than the area of the roof, which also covers the thickness of the walls and the eaves.

In most English towns the amount of roof space for each person cannot be estimated higher than 60 square feet, and in some poor districts is much less. Taking the rainfall in all England at 30 inches, and assuming that all is saved, and that there is no loss from evaporation, the receiving surface for each person would give 935 gallons, or $2\frac{1}{2}$ gallons a day. But as few town houses have any reservoirs, this quantity runs in great part to waste in urban districts. In the country it is an important source of supply, being stored in cisterns or water butts. If, instead of the roof of a house, the receiving surface be a piece of land, the amount may be calculated in the same way. It must be understood, however, that this is the total amount reaching the ground; all of this will not be available; some will sink into the ground, and some will evaporate; the quantity lost in this way will vary with the soil and the season from the one-half to seven-eighths. To facilitate these calculations, tables have been constructed by engineers.[1]

One inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons by weight) on each square acre.[2]

In estimating the annual yield of water from rainfall, and the yield at any one time, we ought to know the greatest annual rainfall, the least, the average, the period of the year when it falls, and the length of the rainless season. The greatest fall is generally about one-third more, and the least one-third less than the average. The average of the three driest years is a safe basis. It must also be remembered that the amount of rainfall differs very greatly even in places near together.

Springs, Rivers.—It will often be a matter of great importance to determine the yield of springs and small rivers, as a body of men may have to be placed for some time in a particular spot, and no engineering opinion, perhaps, can be obtained.

A spring is measured most easily by receiving the water into a vessel of known capacity, and timing the rate of filling. The spring should be opened up if necessary, and the vessel should be of large size. The vessel may be measured either by filling it first by means of a known (pint or gallon) measure, or by gauging it. If it be round or square, its capacity can be at once known, by measuring it, and using the rules laid down in the chapter for measuring the cubic amount of air in rooms. The capacity of the vessel in cubic feet may be brought into gallons, if desirable, by multiplying by 6·23. If a tub or cask only be procurable, and if there is no pint or gallon measure at hand, the following rule may be useful:—

Take the bung diameter in inches, by measuring the circumference at the bung, dividing by 3·1416, and making an allowance for the thickness of the staves; square the bung diameter, and multiply by 39. Take the head diameter in inches by direct measurement, and square it, and multiply by 25. Multiply one diameter by the other, and the product by 26. Add

[1] Beardmore's *Manual of Hydrology*, p. 61; see also table in Appendix E.

[2] To bring cubic inches into gallons, multiply by 40 and divide by 11,091, or multiply at once by ·003607.

the sums, and multiply by the length of the cask in inches; then multiply by ·000031473, and the result is given in gallons.[1]

When it is required to ascertain the yield of any small water-course with some nicety, it is the practice of engineers to dam up the whole stream, and convey the water by some artificial channel of known dimensions.

1. A wooden trough of a certain length, in which the depth of water and the time which a float takes to pass from one end to the other is measured.

2. A sluice of known size, in which the difference of level of the water above and below the sluice is measured.[2]

3. A weir formed by a plank set on edge in which a rectangular notch is cut, usually one foot in width; over this the water flows in a thin sheet, and the difference of level is measured by the depth of the water as it flows over the notch. Then by means of a table the amount of water delivered per minute is read off. The weir must be formed of very thin board and be perfectly level; a plumb-line has generally to be used.[3] This plan of measuring the yield of water-courses is the one now most generally adopted by engineers.

The same object may, however, be attained with sufficient accuracy for the purposes of the medical officer by selecting a portion of the stream where the channel is pretty uniform, for the length of, say not less than 12 or 15 yards, and in the course of which there are no eddies. Take the breadth and the average depth in three or four places, to obtain the sectional area. Then, dropping in a chip of wood, or other light object, notice how long it takes to float a certain distance over the portion of channel chosen. From this can be got the surface velocity per second, which is greater of course than the bottom or the mean velocity. Take four-fifths of the surface velocity (being nearly the proportion of mean to surface velocity), and multiply by the sectional area. The result will be the yield of the stream per second.

It may sometimes be worth while, if labour be at hand, to remove some of the irregularities of the channel, or even to dig a new one across the neck of a bend in the course of the stream.

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1 Nesbit's *Practical Mensuration*, 1859, p. 309. Another rule, applicable to common forms of casks, is to multiply the cube of the diagonal by 0·002255 or by $\frac{1}{443}$; the cube of the diagonal is got by adding the square of half the sum of the diameters in inches to the square of half the length;—then this sum multiplied by its square root gives the cube of the diagonal. Another is the following:—Find the middle diameter, that is the diameter mid-way between the bung and the head, and call it M; head diameter H; bung diameter B; length of cask L; then $(H^2+B^2+4\,M^2)\times L\times 0{\cdot}0004721$ will give the content in gallons. These and many other useful calculations can be very conveniently done by means of the common or carpenter's slide-rule.

2 *Discharge of water through a sluice.*—Multiply breadth of opening by the height; this gives the area of the sluice.

Discharge = area multiplied by five times the square root of head of water in feet.—The head of water is the difference of level of the water above and below the dam if the sluice be entirely under the lower level; or the height of the upper level above the centre of the opening if the sluice be above the lower level.

3 *Discharge of water over a weir one foot in length.*—If the weir is more or less than a foot, multiply the quantity in the table opposite the given depth by the length of the weir in feet, or decimals of a foot.

Depth falling over, inches.	Discharge per minute.	Depth falling over, inches.	Discharge per minute.
½	1·70 cubic feet.	2½	19·70 cubic feet.
1	4·82 ,, ,,	3	26·62 ,, ,,
1½	8·84 ,, ,,	3½	33·22 ,, ,,
2	13·63 ,, ,,	4	40·71 ,, ,,

Thus if the weir measure 1 foot, and the depth of water falling over be 2 inches, the delivery is read at once, viz., 13·63 cubic feet, or 84·9 gallons per minute.

The yield of a spring or small river should be determined several times, and at different periods of the day.

Wells.—The yields of wells can only be known by pumping out the water to a certain level and noticing the length of time required for refilling. In cases of copious flow of water a steam-engine is necessary to make any impression; but, in other cases, pumping by hand or horse labour may be sufficient perceptibly to depress the water, and then, if the quantity taken out be measured, and the time taken for refilling the well be noted, an approximate estimate can be formed of the yield.

Permanence of Supply.—It is obvious that the permanence of the supply of a spring or small stream may often be of the greatest moment in the case of an encampment, or in the establishment of a permanent station.

In the first place, evidence should, when available, be obtained. If no evidence can be got, and if the amount and period of rain be not known, it is almost impossible to arrive at any safe conclusion. The country which forms the gathering ground for the springs or rivers should be considered. If there be an extensive background of hills, the springs towards the foot of the hills will probably be permanent. In a flat country the permanency is doubtful, unless there be some evidence from the temperature of the spring that the water comes from some depth. In limestone regions springs are often fed from subterranean reservoirs, caused by the gradual solution of the rocks by the water charged with carbonic acid; and such springs are very permanent. In the chalk districts there are few springs or streams, on account of the porosity of the soil, unless at the point the level be considerably below that of the country generally. The same may be said of the sandstone formations, both old and new; but deep wells in the sandstone often yield largely, as the permeable rocks form a vast reservoir. In the granitic and trap districts small streams are liable to great variations, unless fed from lakes; springs are more permanent when they exist, being perhaps fed from large collections or lochs.

2. Storage.

The amount of storage required will depend on circumstances, viz., the amount used and the ease of replenishing. It is, of course, easy to calculate the space required when these conditions are known, in this way:—the number of gallons required daily for the whole population must be divided by 6·23 to bring into cubic feet, and multiplied by the number of days which the storage must last; the product is the necessary size of the reservoir in cubic feet. Hawksley's formula for storage is as follows:—$\frac{1000}{\sqrt{F}}$, where F equals the annual rainfall in inches; the resulting number is the number of days' storage required. Thus, with a rainfall of 25 inches, we have $\frac{1000}{\sqrt{25}} = \frac{1000}{5} = 200$ days.

Many waters, particularly rain water, must be filtered through sand before they pass into small cisterns, and the filter should be cleaned every three or four months. Fig. 1 is a single filter recommended by the Barrack Commission.[1]

A double filter can be made by having a second chamber.

Whatever be the size of the reservoir, it should be kept carefully clean, and no possible source of contamination should be permitted. In the large

[1] *Report on the Mediterranean Stations,* 1863.

reservoirs for town supply the water is sometimes rendered impure by floods washing surface refuse into them, or by substances being thrown in. In fact, in some cases, water pure at its source becomes impure in the reservoirs.

Some large cities are still supplied principally by rain-water, as Constantinople—where under the houses are enormous cisterns,—Venice, and other places. Gibraltar and Malta are in part supplied in this way.

As far as possible, all reservoirs, tanks, &c., should be covered in and ventilated; in form they should be deep rather than extended, so as to lessen evaporation and secure coolness. Though they should be periodically and carefully cleaned, it would appear that it is not always wise to disturb water plants which may be growing in them; some plants, as *Protococcus*, *Chara*, and others, give out a very large amount of oxygen, and thus oxidise and render innocuous the organic matter which may be dissolved in the water or volatilised from the surface.[1] Dr Chevers mentions that the water of some tanks which were ordered to be cleared of water plants by Sir Charles

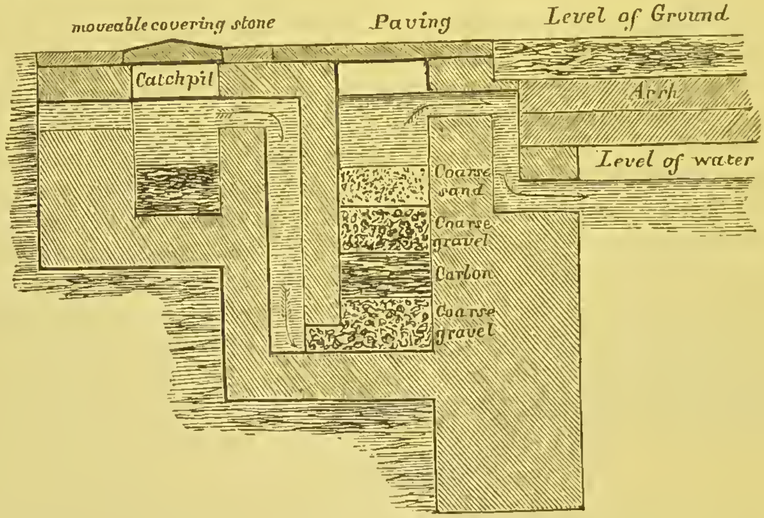

Fig. 1.

Napier deteriorated in quality. Other plants, however, as some species of duckweed (*Lemna* at home, *Pistia* in the tropics), are said to contain an acrid matter which they give off to the water. It would be well to remove some of the plant, place it in pure water in a glass vessel, and try by experiment whether the amount of organic matter in the water is increased, or whether any taste is given to the water. The presence of some of the *Nostoc* family gives rise to an offensive pig-pen odour when decaying.[2] Dead vegetable matter should never find its way into, or at any rate remain in, the reservoir.

Whenever a reservoir is so large that it cannot be covered in, a second smaller covered tank, capable of holding a few days' supply, might be provided, and this might be fitted with a filter, through which the water of the large reservoir might be led as required.

When tanks are large they are made of earth, stones, or masonry; if mortar be used it should, as in the case of the smaller reservoirs, be hydraulic, so that it may not be acted on by the water.

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[1] Clemens, in *Archiv für Physiol. Heilk.*, 1853.
[2] Farlow, *Supplement to First Annual Report of State Board of Health, &c., of Massachusetts*, 1877, p. 143.

The materials of small reservoirs and cisterns are stone, cement, brick, slate, tiles, lead, zinc, and iron. Glass-lined wooden cisterns have also been proposed. Of these slate is the best, but it is rather liable to leakage, and must be set in good cement or in Spence's metal; common mortar must not be used for stone or cement, as lime is taken up and the water becomes hard.[1] Leaden cisterns, as in the case of leaden pipes, often yield lead to water, and should be used as little as possible, or should be protected. Leaden cisterns are corroded by mud or mortar, even when no lead is dissolved in the water. Iron cisterns and pipes are often rapidly eaten away; they are now sometimes protected by being covered inside with Portland cement or with a vitreous glaze. Crease's patent cement is a very useful covering. Barff's process of producing the magnetic oxide on the surface of iron has been tried, but seems hardly so successful as it promised. Galvanised iron tanks are also very much used. They must be covered, and in India be protected from the sun. Zinc has been recommended, but water passing through zinc pipes, or kept in zinc pails, or in so-called galvanised iron vessels, may produce symptoms of metallic poisoning,[2] and even taste strongly of zinc salts, especially if the water is rich in nitrates. It would certainly be best to abandon lead, zinc, and galvanised iron as materials for cisterns, as much as possible, unless we are sure that the water contains no substance likely to act upon the metal.

Cisterns should always be well covered, protected as much as possible from both heat and light, and thoroughly ventilated if they are of any size. Care should always be taken that there is no chance of leakage of pipes into them. A common source of contamination is an overflow pipe passing direct into a sewer, so that the sewer gases pass up, and, being confined by the cover of the cistern, are absorbed by the water; to prevent this, the overflow pipe is curved so as to retain a little water and form a trap, but the water often evaporates, or the gases force their way through it; no overflow pipe should therefore open into a sewer, but should end *above* ground over a trapped grating.[3] A cistern supplying a water-closet should not be used to supply cooking and drinking water, as the pipes leading to the closet often conduct closet air to the cistern. Hence, a small cistern (water-waste preventer) should be used for each closet. Cisterns should be periodically and carefully inspected; and in every new building, if they are placed at the top of the house, convenient means of access should be provided.

Tanks to hold rain-water require constant inspection.

Wells (which are really reservoirs) are very liable to contamination from surface washings during rains. A good coping will often prevent this; but, if there is much subsoil soaking, lining with iron to a certain depth, or covering with brickwork set in cement for a sufficient depth to arrest the flow, is desirable.

3. Distribution.

When houses are removed from sources of water the supply should be by aqueducts and pipes. The distribution by hand is rude and objectionable,

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[1] In two cases in Ireland (at Belturbet and Monaghan) so much lime was taken up from the lining of the tanks that the water was strongly alkaline and tasted caustic. See Report on Hygiene, *Army Medical Reports*, vol. xix. p. 170.

[2] Dr Orsborn, formerly of Bitterne, saw several cases of this kind. See also Downes, *Sanitary Record*, vol. ix. p. 333.

[3] For an instance of enteric fever produced by this cause, see *Lectures on State Medicine*, by F. de Chaumont, pp. 76, 77. See also Dr Blaxall's *Report on Enteric Fever at Ilkeston in* 1880.

for it is impossible to supply the proper quantity, and the risks of contamination are increased. Some of the most extraordinary of the Roman works in both the Eastern and Western Empires were undertaken for the supply of water—works whose ruins excite the astonishment and should rouse the emulation of modern nations.

The plans for the distribution of water should include arrangements for the easy and immediate removal of dirty water. This is an essential point, for in many towns where houses are not properly arranged for small families, there are no means of getting rid of water from the upper rooms, and this inconvenience actually limits the use of water, even when its supply is ample.

The supply of water to houses may be on one of two systems, intermittent or constant. The difference between the two plans is, that in the first case there is storage in the houses for from one to three days; while in the latter case there is either no storage, or it is only on a very small scale for two purposes, viz., for water-closets and for the supply of kitchen boilers.[1] It should, however, be understood that the constant supply has not always meant in practice an unlimited supply, nor has it been the case that the water in the house-pipes was always in direct communication with the water in the reservoirs. On the contrary, the water to the houses has often been cut off, particularly in places where the supply was limited, and the fittings not good, and where there was great waste.

The great arguments against storage on the premises (except on a limited scale for closets and boilers) are the chances of contamination in cisterns, and the very imperfect means of storage. In poor houses wooden casks or barrels are often used, and may be placed in the worst situations. Although the arguments against the storage system are directed in part against removable failures, it must, however, be admitted that, especially in poor houses, the inspection and cleansing even of a well-placed cistern will never be properly done, and that with all precautions the chances of contamination of the water during storage are very great. As regards this point, the constant system has a very great superiority, for there is no chance of contamination except in the reservoir or in the pipes. So great an advantage is this in a sanitary point of view, that almost all those who have paid most attention to sanitary affairs have advocated the constant system. It is, however, quite necessary that it should be understood what the constant system sometimes has been in practice. When there is an abundance of water, as at Glasgow, the stoppages of water may have been few, but, when water has had to be economised, the water has been from time to time shut off from the house-pipes, and then no water has been procurable for hours. This, however, is avoided as much as possible in the day time, so that the inconvenience is reduced to a minimum. In some cases, again, in order to economise water, a throttle or ferule has been introduced into the communication or house pipe,[2] lessening the diameter to $\frac{1}{8}$th or even to $\frac{1}{16}$th of an inch, or smaller, so that if the head of pressure be small the water flows very slowly, and sometimes merely dribbles. In other cases a meter is put on a pipe communicating with several houses, and the owner of the houses is charged for the water, and this leads him to enforce a very

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1 Much valuable evidence on the constant supply may be found in the *Report of the House of Commons Committee on the East London Water Bills*, 1867.

2 The terms used to describe the pipes differ a little apparently; the mains and district or sub-mains are the large pipes, which are always full of water, the latter being of course the smaller; the service-pipe is another term for a district main. The communication-pipe is that which runs from the service-pipe to the house, and in the house it takes the name of house-pipe.

sparing use of it. In all these ways the constant system may tell against the consumer, while, on the other hand, great waste, leaking fittings, and fraudulent abstraction of water (to avoid which there are several ingenious contrivances) tell against the company, and lead to a depreciation of their property.

In spite of all these difficulties the system of constant supply, in some shape or other, has been carried out in a large number of towns in England;[1] and the Metropolis Water Act of 1871 ordered constant supply for London, if demanded by the ratepayers, and if proper fittings are provided.

In providing a constant supply, certain precautions are necessary. The fittings must be as perfect as possible. In some cases, when the system has been changed from the intermittent to the constant system, as in Chester, the waste of water was so great that the old plan was recurred to. But when the fittings are good there is real economy in the constant system,—as shown in the comparison between Lincoln and Oxford, and by Hawksley's evidence with reference to Norwich.[2] Common taps do not answer, and the best screw taps and fittings must be used.[3] To prevent theft, it has been proposed to make the removal of fittings a specific offence, punished summarily by imprisonment, and to place the sale of such property under the same restrictions as in the case of Crown property.

One important sanitary advantage of the constant system is that, in order to facilitate inspection and detection of waste, no waste pipe is allowed to open into a sewer, but it is always so placed that any escape of water can be easily seen (the so-called warning pipe). The great evil of sewer gases being conducted back into houses through overflow pipes is thus avoided. Careful inspection and good fittings so far lessen the waste of the constant system, that in some cases less water is used than under the intermittent plan.[4]

Mr G. Deacon, in a very interesting and instructive paper,[5] has shown that the loss on the constant system is due to causes over which the consumer has generally little or no control, and that it occurs for the most part before the water reaches him. It arises chiefly from leaks in pipes, drawn joints, and so on, and up to lately there were no means of detecting this in a way practically useful. By the introduction of his water-waste meter this is now done with the utmost precision and accuracy, so that now in Liverpool the expenditure of water has been reduced from 33·5 gallons per head per diem to 13·3. This does not mean any restriction to the consumer; the supply is now absolutely constant, and the use unlimited. But it means that formerly the consumer used only 13 gallons at the outside, whilst 20 gallons went to pure waste. Mr Louttit[6] stated that the Lambeth Water Company was able by this means to reduce their expenditure from 35·09 to 15·28 per head. The general waste in London appears to be about 15 gallons per head out of a total of about 35. With such a system of checking, the main difficulties of a constant supply seem to be solved, even if every consumer used the full 25 gallons laid down in this work. Further

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[1] Mr Beggs' Pamphlet, *op. cit.*, page 20.

[2] See *Report of Rivers Pollution Commission*, vol. vi. p. 233.

[3] A bad ball-cock has been known to drop 12 gallons a day.

[4] Evidence of Mr Easton in the *Report of Committee on the East London Water Bills*, 1867.

[5] "The Constant Supply and Waste of Water," by George F. Deacon, M. Inst. C.E., *Journal of the Society of Arts*, vol. xxx. p. 738, 1882.

[6] Discussion on Mr Deacon's paper. According to Sir F. Bolton, in the Lambeth district in six years ending March 31st 1883, the delivery was on the average 33·6; in the year ending March 31st 1884 it was only 29·85; and later in 1884, on the constant system, it was only 20·51, but required constant inspection.

improvements in the direction of detecting leakage have been made in Germany, where the microphone was brought usefully into play.

Some engineers have proposed what may be called a compromise between the intermittent and constant systems. The objection to this plan is that cisterns are reintroduced, and their lessened size does not remove the objections to them.

If the constant system is used, a good screw stop-cock, available to the tenant, should be placed at the point of the entrance of the pipe into the house, so that the water may be turned off if pipes burst, or to allow the pipes to be empty, as during frost. Every precaution must be taken that impure water is not drawn into the pipes by a pipe being emptied and sucking up water from a distance.[1]

For the supply of a very large city, it might be desirable to divide the city into sections, and to establish a reservoir for each district, holding three or four days' supply. In this way the waste of one section would not take away the water from another. In some instances, people in one part of a town, supplied on the constant system, have used so much water for gardens that other parts have been altogether deprived of supply. The system of secondary reservoirs would not only lessen this chance, but would make it possible to ascertain that every part of the town was getting its supply. The number of water companies in London has in fact somewhat this effect, but the subdivision is not carried far enough.

There is no doubt that the constant system is the safer, especially for poor houses, as it leaves no loophole for inattention in the cleansing of cisterns. Only, it requires that the constant system should really fulfil the conditions laid down for it, viz., it should deliver sufficient water at all times, and not merely delude us with a phrase.

In both plans the water is conducted from the reservoirs in pipes. The pipes are composed of iron, masonry, or earthenware, for the larger pipes or mains, the iron being sometimes tinned or galvanised, or lined with concrete, or pitched, or covered with a vitreous glaze, such as that patented by De Lavenant; for the smaller pipes, iron, lead, tin, zinc, tinned copper, earthenware, gutta percha, &c., are used.

Pipes of artificial stone are now made. Iron is the best material for the larger pipes, and it is also necessary (steam-piping) for the smaller pipes under the pressure of the constant service system.

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[1] The Board of Trade issued a Minute in 1872, laying down regulations and defining the kind of fittings and arrangements for London. The following are the principal points. Lead pipes to be of certain strength (if internal diameter is ⅜ in., ½ in., ⅝ in., ¾ in., 1 in., 1¼ in., the respective weights per lineal yard are to be 5 lb, 6 lb, 7½ lb, 9 lb, 12 lb, 16 lb.). Every pipe in contact with the ground to be of lead; each house to have a communication pipe, but only one, unless an owner has it for a block of houses; connection of every communication pipe to be by a brass screwed ferule or stop-cock with a clear area of water-way equal to ½ inch; every joint to be a "plumbing" or "wipe" joint. No pipe to pass through an ash-pit, manure heap, drain, unless it cannot be avoided, and then the pipe is to be laid in an exterior cast-iron pipe or jacket; each pipe in the ground to be 30 inches below surface; each communication pipe to have near the entrance into the house a screwdown stop-valve; if in the ground such valve to be protected by proper cover and guard-box; every cistern to be water-tight, to have a good "ball-tap"; no waste-pipe except a "warning pipe," and such warning pipe to be so placed as to be easily inspected. No cistern buried in ground to be used; wooden cisterns to have metallic linings; every water-closet, urinal, or boiler shall be served only from a cistern, and shall not be in direct communication with the water-pipes; closets and urinals to have water-waste preventers; every "down-pipe" into a water-closet to have an internal diameter of not less than 1¼ inch, and to weigh not less than 9 lb per lineal yard. No bath to have an overflow-pipe except of the "warning" kind; the outlet must be distinct from the inlet, and the inlet shall be higher than the highest stand of the water. Lead warning pipes of which the ends are open, and which cannot remain charged with water, may have the following minimum weight: ½ inch in diameter to have a weight 3 lb per yard; ¾ in., 5 lb; 1 in., 7 lb.

Water should be distributed not only to every house, but to every floor in a house. If this is not done, if labour is scarce in the houses of poor people, the water is used several times; it becomes a question of labour and trouble *versus* cleanliness and health, and the latter too often give way. Means must also be devised for the speedy removal of dirty water from houses for the same reasons. In fact, houses let out in lodgings should be looked upon, not as single houses, but as a collection of dwellings, as they really are.

ACTION OF WATER ON LEAD PIPES.

There are more discrepancies of opinion on this subject than might have been anticipated.

From an analysis of most of the works, the following points appear to be the most certain :—

1. The waters which act most on lead are the purest and most highly oxygenated; also those containing organic matter, nitrites (Medlock),[1] nitrates,[2] and, according to several observers, chlorides.[3] Besides the portion dissolved, a film or crust is often formed, especially at the line of contact of water and air; this crust consists usually of two parts of lead carbonate and one part of hydrated oxide. The mud of several rivers, even the Thames, will corrode lead, probably from the organic matter it contains, but it does not necessarily follow that any lead has been dissolved in the water. Bits of mortar will also corrode lead.

2. The waters which act least on lead are those containing carbonic acid,[4] calcium carbonate, calcium phosphate (which has been found by Frankland to have a great protective power), and in a less degree calcium sulphate, and perhaps, in a still less degree, magnesian salts, and the alkaline phosphates;[5] but it has been said that perfectly pure water, containing no gases, has no action on lead. This, however, is not strictly correct, as pure distilled water has been known at Netley to take up lead from a leaden pipe. The deposit which frequently coats the lead consists of carbonate, phosphate, and sulphate of lead, calcium, and magnesium, if the water have contained these salts, and lead chloride.[6]

3. From the observations of Graham, Hofmann, and Miller, the protective influence of carbonic acid gas appears to be very great; a difficultly soluble lead carbonate is formed. However, a very great excess of free carbonic acid may dissolve this. This has perhaps led to the statement that carbonic acid counteracts the preservative effects of the salts. Water charged with carbonic acid under pressure has a very marked solvent action on lead (Pattison Muir).

Other substances may find their way into water which may act on lead—as vegetable and fatty acids, arising from fruits, vegetables, &c., or sour milk or cider, &c.

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[1] Medlock attributes the greatest influence to ammonium nitrite formed from organic matter; lead nitrite is rapidly formed, and carbonate is then produced; the nitrous acid being set free to act on another portion of lead. Ammonium nitrite exists in most distilled water.

[2] Pattison Muir attributes very powerful action to nitrates, but says that it is modified or even arrested by the presence of carbonates, sulphates, and chlorides, but there is some discrepancy of opinion as to the action of the chlorides.

[3] Pattison Muir found that a solution of sulphate or chloride of ammonium of 0·04 per cent. took up 2·2 grains per gallon after exposure to lead for 505 hours.

[4] M. Langlois (*Rec. de Mém. de Med. Mil.*, 1865, p. 412) attributes a great action on lead to the carbonic acid, but states that the carbonate of lime entirely protects lead, apparently by rendering the carbonic acid inactive.

[5] *Report of the Government Commission*, 1851, p. 7.

[6] Lauder Lindsay, *Action of Hard Water on Lead*, p. 7.

Humus acids are met with in well waters, and these are known to corrode iron, and would in all probability affect lead also.[1]

4. The lead itself is more easily acted upon if other metals, as iron, zinc, or tin, are in juxtaposition; galvanic action is produced. Bending lead pipes against the grain, and thus exposing the structure of the metal, also increases the risk of solution; zinc pipes, into the composition of which lead often enters, yield lead in large quantities to water, and this has been especially the case with the distilled water on board ships.

AMOUNT OF DISSOLVED LEAD WHICH WILL PRODUCE SYMPTOMS OF POISONING.

Dr Angus Smith refers to cases of lead paralysis in which as little as $\frac{1}{100}$th of a grain per gallon was in the water. Adams[2] also speaks of $\frac{1}{100}$th of a grain causing poisoning. Graham speaks of $\frac{1}{57}$th of a grain per gallon as being innocuous. Angus Smith says that $\frac{1}{40}$th of a grain per gallon may affect some persons, while $\frac{1}{10}$th of a grain per gallon may be required for others.[3] But it is difficult to prove it may not at some time have been more than this. Calvert found that water which had been decidedly injurious in Manchester contained from $\frac{1}{10}$th to $\frac{3}{10}$ths of a grain per gallon.

In the celebrated case of the poisoning of Louis Philippe's family at Claremont, the amount of lead was $\frac{7}{10}$ths of a grain per gallon; this quantity affected 34 per cent. of those who drank the water.

The water of Edinburgh is said to contain only $\frac{1}{140}$th of a grain per gallon, which is not hurtful.[4]

On the whole, it seems probable that any quantity over $\frac{1}{20}$th of a grain per gallon ($= \frac{1}{14}$ per 100,000) should be considered dangerous, and that some persons may even be affected by less quantities.[5]

PROTECTION OF LEAD PIPES.

The chief means which have been proposed are:—

(*a*) Lining with tin. Calvert's experiments[6] show that extra tinned and ordinary tinned lead piping both gave up lead to the pure water now used at Manchester.

(*b*) A much better plan is by having a good block-tin pipe enclosed in a lead pipe, as in Haines' patent. If the tin is good it is little acted on, and the strength of the pipe is increased, while bends and junctions can be made without destroying the continuity of the tin. The composite pipes of this

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[1] Rev. A. Irving, on well at Wellington College, also at Castle Malwood in the New Forest (Sir W. V. Harcourt's). Loch Katrine water is also said to corrode boilers (*Geological Magazine*, Sept. 1883 and June 1885; also Decade iii. vol. ii. p. 21; see also Alexis A. Julien, "On the Geological Action of the Humus Acids," in *Proc. of American Assoc. for Advancement of Science*, 1879, p. 311).

[2] *Trans. of the American Medical Society*, 1852, p. 163.

[3] Wanklyn adopts $\frac{1}{10}$th of a grain per gallon as justifying rejection of a water:—$\frac{1}{20}$th would probably be a safer limit. These quantities, reduced to parts per 100,000, would be as follows:—

Per gallon.		Per 100,000.
$\frac{1}{100}$	=	$\frac{1}{70}$
$\frac{1}{10}$	=	$\frac{1}{7}$
$\frac{3}{10}$	=	$\frac{3}{7}$
$\frac{7}{10}$	=	1
$\frac{1}{140}$	=	$\frac{1}{98}$
$\frac{1}{40}$	=	$\frac{1}{28}$
$\frac{1}{57}$	=	$\frac{1}{40}$

[4] *Chemical News*, September 28, 1861.

[5] See also Taylor's *Med. Jurisp.*, 1865, p. 242; and opinions of Penny, *ibid.*, p. 241.

[6] *Chemical News*, September 28, 1861.

kind made by Messrs Walker, Parker, & Co. are said to withstand any amount of torsion. Lead alloyed with 3 per cent. of tin is said not to be acted upon by water (Cameron);[1] pipes of this kind appear to be used in Dublin and in Glasgow. Later experience with this alloy, however, seems to have modified the good opinion first held of it; it is certainly inapplicable to cisterns, or for any purpose where it is more or less exposed to the air.

(*c*) Fusible metal, viz., lead, bismuth, and tin. This is certainly objectionable.

(*d*) Bituminous coating (M'Dougall's patent). This is said to be effectual, but no exact experiments have been recorded.

(*e*) Various gums, resins, gutta percha, and india-rubber. These would probably be efficacious, but there does not seem to be any evidence to show how long they will adhere.

(*f*) Coating interior of pipes with lead sulphide by boiling the pipes in sodium sulphide for fifteen minutes. The sodium sulphide may be made by boiling sulphur in liquor sodæ (Schwartz's patent).

(*g*) Varnish of coal tar.[2]

SUBSTITUTES FOR LEAD PIPES.

Cast and wrought iron pipes can be used, and Mr Rawlinson now orders no others. The iron can be glazed internally. Iron pipes coated inside with Angus Smith's bituminous varnish are now used a good deal, but the tarry taste lingers in the water a long time. Copper tinned and block-tin are also employed, and both are excellent, but are rather expensive. In some cases the tin is eaten through, but this is not common,[3] except with well waters containing nitrates.

SECTION II.

QUALITY OF DRINKING WATER.

SUB-SECTION I.—COMPOSITION.

The composition of water is of importance for several economic purposes; for certain trades which require careful processes of washing and dyeing; for the supply of engines, &c. But these subjects are too technical to be discussed here, and this chapter is therefore restricted to the quality of water as used for drinking purposes. The only domestic matter of importance connected with quality, apart from drinking and cooking, is the relative amount of soap used by hard and soft water in washing. But this is so obvious a matter that it only requires to be alluded to.

Owing to many of the domestic uses of water, such as the washing of utensils, the supply for closets, &c., not requiring a very pure water, it has been proposed in some cases to supply water from two sources—one pure for drinking and cooking, and the other impure. This requires, however, two sets of pipes, and involves the chance of mistake between two waters; and it is only likely to be of use under exceptional circumstances.

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[1] *Manual of Hygiene for Ireland*, p. 218.

[2] Lauder Lindsay, *Action of Hard Water on Lead*, p. 21.

[3] I have seen block-tin pipes eaten through by water at Woolston, apparently in consequence of the presence of nitrates. Zinc pipes, which have been recommended, are objectionable as likely to yield poisonous salts to such waters.—[F. de C.]

Drinking water is supplied from shallow, deep, and Artesian well sources: rain, rivers, wells, springs, &c.

Rain-Water.—As it falls through the air, rain becomes highly aërated (average, 25 cubic centimetres per litre), the oxygen being in larger proportion than in atmospheric air (32 per cent., or a little more); carbon dioxide constitutes $2\frac{1}{2}$ or 3 per cent. of the gas. It carries down from the air ammoniacal salts (carbonate, nitrite, and nitrate), and nitrous and nitric acids in small amount. The total quantity of nitrogen in ammoniacal salts, nitrous and nitric acid, is ·0985 parts per 100,000. Frankland puts the average at ·032. At Montsouris,[1] mean of seven years, the ammonia amounted to ·193 per 100,000; mean of all Paris (1881–82), 0·287 per 100,000; the nitric acid (NO_3), mean of six years, to ·354 per 100,000. This gives a total nitrogen, from ammonia and nitric acid, of ·239 per 100,000. In towns with coal-fires it takes up sulphurous and sulphuric acids, and sometimes hydrogen sulphide. The sulphates in rain increase, according to Dr Angus Smith,[2] as we pass inland, and before large towns are reached; they are, according to this author, "the measure of the sewage in air" when the sulphur derived from the combustion of coal can be excluded, but in this country the exclusion could never be made. Free acids are not found with certainty, according to Smith, when combustion and manufactures are not the cause. The acidity taken as sulphuric anhydride (SO_3) was equal to ·014 grains per 100,000 of rain in a country place in Scotland, and 1·513 in Glasgow; in Manchester in 1870 it was 1·202; and in London ·387. The nitric acid in Glasgow was as much as ·244 parts per 100,000, and in London only ·0884. Albuminoid ammonia was no less than ·0326 parts per 100,000 in London rain.[3] Rain also carries down many solid substances, as sodium chloride, in sea air; calcium carbonate, sulphate, and phosphate; ferric oxide; carbon.[4] It almost always contains also a little nitrogenous organic matter, amounting in extreme cases to as much as ·35 grains per gallon. The total amount of solids from five analyses quoted by Moleschott was 3·2 parts per 100,000, and from 63 samples by Frankland 3·86 per 100,000.[5]

Occasionally microscopic plants of the lowest order (as *Protococcus pluvialis* and others) are present, and in towns the débris arising from street dust.

With regard to Rain as a source of supply.—The uncertainty of the rainfall from year to year, the length of the dry season in many countries, and the large size of the reservoirs which are then required, are disadvantages. On the other hand, its general purity and its great aëration make it both healthy and pleasant. The greatest benefits have resulted in many cases (especially in some of the West Indian Islands) from the use of rain instead of spring or well water, which is often largely impregnated with earthy salts. In all places where the spring or well water is thus bad, as in the neutral ground

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1 *Annuaire de l'Observatoire de Montsouris.*

2 *Air and Rain*, 1872, p. 245.

3 Angus Smith, *op. cit.*, p. 363.

4 An ingenious plan for removing suspended matter from rain-water is supplied by Roberts' (formerly Buck's) "Patent Percolator," which may be attached to the pipe supplying a rain-water tank. It works automatically and produces good results, although at the expense of considerable waste of the water.

5 In rain-water collected at St Albans, in the middle of an arable field, two feet from the ground, Frankland found as much as 8·58 parts in 100,000; from the roof of the Land's End Hotel (Cornwall) 42·8 per 100,000, of which one-half was chlorides.

In a sample from supply tank in officers' quarters at Portland I found 68·5 per 100,000 of solids, of which about 14 were chlorides; the organic constituents were also very large. In another sample, gathered as collected, 46·5 total solids and 20 chlorides; and in one from a pipe leading to the cookhouse, 84·6 total solids and 20·2 chlorides. In a sample collected through funnels direct into glass bottles, the solids were 9·5, of which 7·0 were volatile, chiefly ammonium chloride, &c.—[F. de C.]

at Gibraltar, rain-water should be substituted. So also it has been suggested that in outbreaks of cholera anywhere, the rain-water is less likely to become contaminated with sewage matters than wells or springs, into which organic matters often find their way in an unaccountable manner.

Ice and Snow Water.—In freezing, water becomes purer, losing a large portion of its saline contents. Even calcium carbonate and sulphate are partially got rid of. The air is at the same time expelled. Ice-water may thus be tolerably pure, but heavy and non-aërated. Snow-water contains the salts of rain-water, with the exception of rather less ammonia. The amounts of carbonic acid and air are very small.

There has long been an opinion that snow-water is unwholesome, but this, if it be true, is probably due to impurities. Ice and snow often contain a good deal of suspended organic matter. Dr Baker Edwards, of Montreal, found three parts per 100,000 in the shore ice and in the river ice.[1] In Northern Europe the poorer classes have the habit of taking the snow lying about their dwellings, and as this is often highly impure with substances thrown out from the house, this water may be unwholesome. It has been conjectured that the spread of the cholera in the Russian winter in 1832 was owing to the use of such snow-water contaminated by excretions. Ice and snow may also be the means of conveying malarious poison to places at a distance.[2]

Dew has occasionally been a source of supply to travellers in sterile regions in South Africa and Australia, and on board ship.[3]

Spring, Well, and River Water.—The rain falling on the ground partly evaporates, partly runs off, and partly sinks in. The relative amounts vary with configuration and density of the ground, and with the circumstances impeding or favouring evaporation, such as temperature, movement of air, &c. In the magnesian limestone districts, about 20 per cent. penetrates; in the New Red Sandstone (Triassic) 25 per cent.; in the chalk 42; in the loose Tertiary sand, 90 to 96.[4]

Penetrating into the ground, the water absorbs a large proportion of carbonic acid from the air in the interstices of the soil, which is much richer (250 times) in CO_2 than the air above. It then passes more or less deeply into the earth, and dissolves everything it meets with which can be taken up in the time, at the temperature, and by the aid of carbonic acid. In some sandy soils there is a deficiency of CO_2, and then the water is also wanting in this gas, and is not fresh and sparkling.

The chemical changes and decompositions which occur in the soil by the action of carbonic acid, and which are probably influenced by diffusion, and perhaps by pressure, as well as by temperature, are extremely curious,[5] but cannot be entered upon here. The most common and simple are the solution of calcium carbonate, and the decomposition of calcium and sodium silicate by carbonic acid, or alkaline carbonates. Salts of ammonia, also,

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[1] Further evidence of the impurity to be sometimes met with in ice will be found in the *Reports of the State Board of Health of Massachusetts*, vols. vii. and x.

[2] See paper by C. Smart, M.B., C.M., Captain and Assistant Surgeon, United States Army, "On Mountain Fever and Malarious Water," *American Journal of Medical Science*, Jan. 1878. See also Report on Hygiene, *A.M.D. Reports*, vol. xix. See also Report by C. Smart, Major and Surgeon, U.S.A., "Public Health in Minnesota," vol. ii. No. 12, 1887.

[3] *Dew-ponds* are also resorted to as a supply for cattle in Hampshire and elsewhere.

[4] For tables of percolation see *Our Homes* (Cassell, 1883), pp. 807, 809. Evans, from twenty-nine years' observations in the chalk of Hemel-Hempstead, gives the summer average at 61 per cent., the winter at 15½, and the whole year at 37½.

[5] These are given in detail by G. Bischof, *Chemical and Physical Geology* (Cavendish Society's edit.), 1854, vol. i. p. 2 *et seq.*; and in Watts's *Dictionary of Chemistry*, Article "Chemistry of Geology," by Dr Paul.

when they exist, appear from Dietrich's observations to have a considerable dissolving effect on the silicates.

Fed from a variety of sources, river water is even more complex in its constitution than spring water; it is also more influenced by the season, and by circumstances connected with season, such as the melting of snow or ice, rains and floods, &c. The water taken on opposite sides of the same river has been found to differ slightly in composition.

The general result of solution and decomposition is, that the water of springs and rivers often contains a great number of constituents—some in very small, others in great amount. Some waters are so highly charged as to be termed mineral waters, and to be unfit for drinking, except as medicines. The impurities of water are not so much influenced by the depth of the spring as by the strata it passes through. The water of a surface spring, or of the deepest Artesian well, may be pure or impure. The temperature of the water also varies, and is chiefly regulated by the depth. The temperature of shallow springs alters with the season; that of deeper springs is often that of the yearly mean. In very deep springs, or in some Artesian wells, the temperature of the water is high.

The substances which are contained in spring, river, and well waters are noted more fully under the head of "EXAMINATION OF WATER." There may be suspended matters, mineral, vegetable, or animal; dissolved gases, viz., nitrogen, oxygen, carbon dioxide, and in some cases hydrogen sulphide, and carburetted hydrogen; and dissolved solid matters, consisting of lime, magnesia, soda, potassa, ammonia, iron, alumina, combined with chlorine, and sulphuric, carbonic, phosphoric, nitric, nitrous, and silicic acids. More infrequently, or in special cases, certain metals, as arsenic, manganese, lead, zinc, and copper, may be present.

The mode of combination of these substances is as yet uncertain; it may be that the acids and bases are equally distributed among each other, or some other modes of combination may be in play. The mode of combination may *usually* be assumed to be as follows. Each separate substance being determined the chlorine is combined with sodium; if there is an excess it is combined with potassium or calcium; if there is an excess of sodium, it is combined with sulphuric acid, or if still in excess, with carbonic acid. Lime is combined with excess of chlorine, or sulphuric acid, or if there be no sulphuric acid, or an excess of lime, with carbonic acid. Magnesia is combined with carbonic acid. So that the most usual combinations are sodium chloride, sodium sulphate, sodium carbonate, calcium carbonate (held in solution by carbonic acid), calcium sulphate, calcium chloride and silicate, and magnesium carbonate; but the results of the analysis may render other combinations necessary.

Distilled Water.—Distillation is now very largely used at sea, and affords an easy way of getting good water from sea or brackish water. Almost any form of apparatus will suffice, if fuel can be procured, to obtain enough water to support life; and if even the simplest appliances are not attainable, the mere suspension of clean woollen clothing over boiling water will enable a large quantity to be collected. At sea, salt water is sometimes mixed with it from the priming of the boilers, and occasionally, from decomposition of magnesium chloride (probably), a little free hydrochloric acid passes off. This can, if necessary, be neutralised by sodium carbonate.

As distilled water is nearly free from air, and is therefore unpalatable to some persons, and is supposed to be indigestible,[1] it may be aërated by

[1] By some even dangerous (Gerardin).

allowing it to run through a cask, the bottom of which is pierced with fine holes, so as to expose the water to the air. Plans for aërating the water distilled from sea-water have been proposed by Normandy and others, and are used in most steamers.

Care should be taken that no lead, zinc, or copper finds its way into the distilled water. Many cases of lead poisoning have occurred on board ships, partly from the use of *minium* in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition. If possible, *block tin* should always be used.

Comparative Value of Spring, River, and Well Water as Sources of Supply.

This depends on many circumstances. Spring water is both pure and impure in different cases; and the mere fact of its being a spring is not, as sometimes imagined, a test of goodness. Frequently, indeed, river water is purer than spring water, especially from the deposit of calcium carbonate; organic matter is, however, generally in greater quantity, as so much more vegetable matter and animal excreta find their way into it. The water of a river may have a very different constitution from that of the springs near its banks. A good example is given by the Ouse, at York: the water of this river is derived chiefly from the millstone grit, which feeds the Swale, the Ure, and the Nid, tributaries of the Ouse; the water contains only 13 parts per 100,000 of salts of calcium, magnesium, sodium, and a little iron. The wells in the neighbourhood pass down into the soft red sandstone (Yoredale series) which lies below the millstone grit; the water contains as much as 92·8 parts, and even, in one case, 137 parts per 100,000; in addition to the usual salts there is much calcium chloride, and calcium, sodium, and magnesium nitrates. Shallow-well water is always to be viewed with suspicion; it is the natural point to which the drainage of a good deal of surrounding land tends, and heavy rains will often wash many substances into it.[1] The question may arise as to what should be considered a shallow, and what a deep well. In the *Rivers Pollution Commissioners' Sixth Report* all the shallow wells examined are less than 50 feet deep; most of the deep wells more than 100 feet deep. Any well less than 50 feet deep that does not pass through an impermeable stratum, such as stiff clay or hard rock, must be classed as a shallow well. The following table is given by the Rivers Pollution Commissioners:[2]—

Wholesome	1. Spring water, . .	very palatable.
	2. Deep-well water, .	
	3. Upland surface water,	moderately palatable.
Suspicious	4. Stored rain-water, .	
	5. Surface water from cultivated land, . .	palatable.
Dangerous	6. River water, to which sewage gains access,	
	7. Shallow-well water, ...	

SUB-SECTION II.—CHARACTERS AND CLASSIFICATION OF DRINKING WATERS.

The general characters of good water are easily enumerated. Perfect clearness; freedom from odour or taste; coolness; good aëration; and a

[1] Dr (now Sir Charles) Cameron (*Dublin Journal of Medical Science*) cites a case where good and bad water were obtained from different levels in the same well. Similar results have been observed elsewhere; see analysis of water from a well at Fareham, Report on Hygiene, *A.M.D. Reports*, vol. xxi. In these cases both samples were impure, but the water from the bottom of the well contained a great excess of salts, due probably to infiltration from the tidal waters of the neighbouring river.

[2] *Sixth Report*, p. 129.

certain degree of softness, so that cooking operations, and especially of vegetables, can be properly performed, are obvious properties. But when we attempt a more complete description, and assign the amounts of the dissolved matters which it is desirable should not be exceeded, we find considerable difference of opinion, and also a real want of evidence on which to base a satisfactory judgment.

Still an hygienic classification or enumeration of potable waters, based on such facts as are generally admitted, will be useful. A division of waters used for drinking into four classes has been adopted in this work:—

1. Pure and wholesome water.
2. Usable ,,
3. Suspicious ,,
4. Impure ,,

The waters belonging to the first and second class may be used; those of the third, or suspicious class, should be well filtered before distribution, and, if possible, should be again filtered in the house. A purer source should also be obtained if possible, and sources of sewage contamination ascertained and prevented.

The waters of the fourth class should be entirely disused, or only be used when a better source is not procurable, and means of purification should then be systematically resorted to.

Sub-Section III.—Origin of the Impurities in Drinking Water.

The origin of the impurities in water may be conveniently referred to four heads, viz.:—(1) substances derived from the source; (2) substances added during the flow of the water in rivers, canals, aqueducts, or other conduits; (3) impurities caused by storage in reservoirs or tanks; and (4) substances added during distribution from reservoirs either in pipes or water barrels, or in house cisterns.

1. *Impurities of Source.*

The geological formation of a district necessarily influences the composition of the water running through it, though it is impossible to tell with absolute certainty what the constituents of the water may be. Formations vary greatly, and the broad features laid down by geologists do not always suffice for our purpose. In the middle of a sandy district, yielding usually a soft water, a hard selenitic water may be found; and, instead of the pure calcium carbonate water, a chalk well may yield a water hard from calcium sulphate and iron. Still it may be useful to give a short summary of the best-known facts.

1. *The Granitic, Metamorphic, Trap Rock, and Clay-Slate Waters.*—Generally the granitic water is very pure, often not containing more than 3 to 9 parts per 100,000 of solids, viz., sodium carbonate and chloride, and a little lime and magnesia. The organic matter is in very small amount. The clay-slate water is generally very pure, often not containing more than from 4 to 5 parts per 100,000. The water from hard trap rocks is pure, but if the trap be disintegrated the shallow wells sunk in it are of course liable to be fouled by surface washings or soakage.

2. *The Water from Millstone Grit and Hard Oolite.*—Like the granitic water this is very pure, often not containing more than 6 to 11 parts per 100,000 of mineral matters, which consist of a little calcium and magnesium sulphate and carbonate; a trace of iron.

3. *Sand-Stone Waters.*—These are of variable composition, but as a rule are impure, containing much sodium chloride, sodium carbonate, sodium sulphate, iron, and a little lime and magnesia, amounting altogether to from 43 to 114 parts per 100,000. The organic matter may be in large amount, —6 to 11 parts per 100,000, or even more. Sometimes these waters are pure and soft, but in other cases wells or springs, within a short distance, may vary considerably in composition.

4. *The Loose Sand and Gravel Waters.*—In this case there is also a great variety of composition. Sometimes the water is very pure, as in the case of the Farnham waters, and in some of the waters from the green sand, where the total solids are not more than from 6 to 11 parts per 100,000, and consist of a little calcium carbonate, sulphate, and silicate; magnesium carbonate; sodium and potassium chloride; sodium and potassium sulphate; iron, and organic matter. The last is sometimes considerable, viz., 1 to 1½ parts per 100,000. In tolerably pure gravels, not near towns, the water is often very free from impurity. In the case of many sands, however, which are rich in salts, the water is impure, the solid contents amounting sometimes to from 70 to 100 parts per 100,000, or more, and consisting of sodium chloride, sodium carbonate, sodium sulphate, with calcium and magnesium salts.[1] These waters are often alkaline, and contain a good deal of organic matter. The water from the sands in the "Landes" (Southern France) contains enough organic matter to give ague.

5. *Waters from the Lias Clays* vary in composition, but are often impure; even 310 parts per 100,000 of mineral matters have been found. No less a quantity than 126 parts of calcium sulphate, and 60 of magnesium sulphate, existed in a water examined by Voelcker.[2]

6. *The Chalk Waters.*—The pure, typical, calcium carbonate water from the chalk is very sparkling and clear, highly charged with carbonic acid, and contains from 10 to 30 parts per 100,000 of calcium carbonate, a little magnesium carbonate and sodium chloride—small and immaterial quantities of iron, silica, potassa, nitric, and phosphoric acids. Sulphuric acid in combination is sometimes present in variable amount; organic matter is usually in small amount. This is a good, wholesome, and pleasant water. It is hard, but softens greatly by boiling.[3]

7. *The Limestone and Magnesian Limestone Waters.*—These are also clear sparkling waters of agreeable taste. They differ from the chalk in containing usually more calcium sulphate (6 to 17 parts, or even more) and less carbonate, and, in the case of the dolomitic districts, much magnesium sulphate and carbonate. Organic matter is usually in small amount. They are not so wholesome as the chalk waters. They are hard, and soften less on boiling.

8. *The Selenitic Waters.*—Water charged with calcium sulphate (9 to 30 parts, or even more) may occur in a variety of cases, but it may sometimes come from selenitic rocks. It is an unwholesome water, and in many persons produces dyspepsia and constipation, alternating with diarrhœa.

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[1] In a shallow well (20 feet deep) in the gravel, near Netley Abbey, the water yielded total solids 212·5, of which were chlorides 124 parts per 100,000; after deepening it to 30 feet, and passing through a stratum of stiff blue clay, it gave only 24 total solids, and 9·3 of chlorides.—[F. de C.]

[2] In a well from Weedon Barracks, 109 feet deep, sunk in blue lias, I found 130 parts per 100,000 of solids, but very little organic matter.—[F. de C.]

[3] Sometimes the water drawn from the upper part of the chalk is really derived from Tertiary sand lying above the chalk. The water contains less calcium carbonate, and more sodium carbonate and chloride, and may be alkaline.

It is hard, softens little on boiling, and is not good for cooking or washing.

9. *Clay Waters.*—Very few springs exist in the stiff clay; the water is chiefly surface, and falls soon into rivers; it varies greatly in composition, and it often contains much suspended matter, but few dissolved constituents, chiefly calcium and sodium salts.

10. *Alluvial Waters.*—(Alluvium is usually a mixture of sand and clay.) Generally impure, with calcium carbonate and sulphate, magnesium sulphate, sodium chloride and carbonate, iron, silica, and often much organic matter. Occasionally the organic matter oxidises rapidly into nitrites, and if the amount of sodium chloride is large, it might be supposed that the water had been contaminated with sewage. The amount of solids per 100,000 varies from 30 to 170 parts or even more.

11. *Surface and Subsoil Water.*—Very variable in composition, but often very impure, and always to be regarded with suspicion. Heaths and moors, on primitive rocks, or on hard millstone grit, may supply a pure water, which may, however, be sometimes slightly coloured with vegetable matter. Cultivated lands, with rich manured soils, give a water containing often both organic matter and salts in large quantity. Some soils contain potassium, sodium, and magnesium nitrates, and give up these salts in large quantity to water. This is the case in several parts of India, at Aden, and at Nassick in the Deccan (Haines). In towns and among the habitations of men, the surface water and the shallow well water often contain large quantities of calcium and sodium nitrites, nitrates, sulphates, phosphates, and chlorides. The nitrates in this case probably arise from ammonia, ammonium nitrite being first formed, which dissolves large quantities of lime. Organic matter exists often in large amount, and slowly oxidises, forming ammonia and nitric acid. In some cases butyric acid, which often unites with lime, is also formed.

12. *Marsh Water.*—This always contains a large amount of vegetable organic matter; it is not unusual to find from 17 to 57 parts per 100,000, and in some cases even more. Suspended organic matter is also common. The salts are variable. A little calcium and sodium in combination with carbonic and sulphuric acids and chlorine are the most usual. Of course, if the marsh is a salt one, the mineral constituents of sea-water are present in varying proportions.

13. *Water from Graveyards.*—Ammonium and calcium nitrites and nitrates, and sometimes fatty acids, and much organic matter. Lefort found a well of water at St Didier, more than 330 feet from a cemetery, to be largely contaminated with ammoniacal salts and an organic matter which was left on evaporation. The water was clear at first, but had a vapid taste, and speedily became putrid. The water from old graveyards (disused) may show less organic matter, but it will contain large quantities of nitrates, chlorides, &c.

14. *Artesian Well Water.*—The composition varies greatly. In some cases the water is so highly charged with saline matter as to be undrinkable: the water of the Artesian well at Grenelle contains enough sodium and potassium carbonates to make it alkaline; there is also often a considerable amount of free (or saline) ammonia. In some cases the water contains an appreciable amount of iron; in other cases, especially when drawn from the lower part of the chalk, or the green sand below it, it is tolerably pure. Its temperature is usually high in proportion to the depth of the well. The aëration of the water is often moderate, sometimes *nil*. These last two points sometimes militate against the employment of water from very deep wells.

15. *Waters from Wells near the Sea.*[1]—This frequently contains so much saline matter as to taste quite brackish, although the organic matter may not be very large. In some samples from Shoeburyness (analysed at Netley) the total solids ranged from 148 to 312 parts per 100,000 of total solids, the chlorides being from 31 to 93: mean of six samples—236 total solids and 50 of chlorides. In one sample, however, the albuminoid ammonia was only 0·007 per 100,000, and in five the oxygen required for organic matter was under 0·075 per 100,000. Samples from wells at Gibraltar yield in some cases large quantities of solids; in one instance as much as 338 parts of total solids and 244 of chlorides in 100,000.[2] At Landguard Fort, water from a boring 150 feet deep yielded more than 700 parts of solids and 540 parts of chlorides.

16. *Rain-Water* may be contaminated by washing the air it falls through, but more by matters on the surface on which it falls, such as decaying leaves, bird droppings, soot, or other matter on the roofs of houses; it also takes lead from lead coatings and pipes, and zinc from zinc roofs. If stored in underground tanks it may also receive soakings from the soil through leakage.

2. *Impurities of Transit from Source to Reservoirs.*

Open conduits are liable to be contaminated by surface washings carrying in finely divided clay, sand, chalk, and animal matters from cultivated land; and the leaves and branches of trees add their contingent of vegetable matters. These impurities may occur in most cases, but in addition the refuse of houses, trades, and factories is often poured into rivers, and all sorts of matters are thus added.

These impurities are broadly divided by the Rivers Pollution Commissioners into "sewage" and "manufacturing": under the former term all solid and liquid excreta, house and waste water, and in fact all impurities coming from dwellings, are included; under the latter term are placed all manufacturing refuse, such as from dye and bleach works, tanneries, paper-making, woollen, silk, and metal works, &c.[3]

The very numerous animal and vegetable substances derived from habitations are usually classed under the vague, but convenient term of "organic matter," as the separation of the individual substances is impossible. The organic matter is usually nitrogenous, and Frankland has proposed to express its amount in terms of its nitrogen (organic nitrogen), but this view is not yet generally received on account of the difficulty of estimating the very small quantity of nitrogen. The nitrogenous organic matter undergoes gradual transformation, and forms ammonia, and nitrous and nitric acids. The exact steps of this process are perhaps complicated. On keeping the water the nitrites disappear, and in some cases the nitrates also gradually diminish, probably from the action of *bacteria.* A. Müller[4] found the residue of well water gave with sodium hydrate a herring-like odour, which seemed like a trimethylamine.

Many of the "organic matters" in water are not actually dissolved, but are so finely suspended that they pass through filtering paper. There is

[1] For a good example of the influence of a tidal river on neighbouring wells, see my *Lectures on State Medicine*, Table x. p. 91.—[F. de C.] On the other hand, springs situated near the sea have been found very pure.

[2] See tables of water analyses in Reports on Hygiene, *Army Medical Reports*, vol. xix., xx., and xxi.

[3] For a full account of all these impurities, and the best mode of dealing with them, the six *Reports of the Pollution Commissioners* must be referred to.

[4] Roth and Lex, *Militär-Gesundheitspfl.*, p. 16.

no doubt that among this "suspended organic matter" many small plants and animals (including *bacteria* and their spores), are always included. It is probably owing to the variation in the quantity of suspended organic matter (living and dead) that water from the same source sometimes gives different results on analysis, even though the water be taken at the same time. During its flow in open conduits, however, a species of purification goes on, by means of subsidence, the action of water-plants, and to some moderate extent by oxidation. On the whole these processes appear in India to render river-water, in spite of all the contaminations it receives, purer than tank and well water.[1] The freedom from noxious substances is also apparently greater in India in the quick-running streams, which may also depend upon purification taking place in them.[2]

3. *Impurities of Storage.*

The chance of substances getting into the water of wells, and tanks,[3] and even of cisterns in houses, is very great. Surface washings and soakage contaminate wells and tanks, and leakages from pipes, passage of foul air through pipes, or direct absorption of air by an uncovered surface of water, introduce impurities into cisterns.[4] It is singular in how many ways cisterns and tank waters get foul, and what care is necessary not only to place the cistern under safe conditions at first, but to examine it from time to time to detect contamination of the water. In India, especially, the tank water is often contaminated by clothes washed near, or actually in, the tank; by the passage even of excrement directly into it, as well as by surface washings, so that in fact in some cases the village tank is one of the chief causes of the sickness of the people. There is, perhaps, no point on which the attention of the sanitary officer should be more constantly fixed than that of the storage of water, either on the large or small scale.

In shallow wells (4 to 30 feet deep) the soakage water from the ground in loose soils of chalk and sand is often very impure. Thus in a town the well-water often shows evidence of nitrites, nitrates, ammonia, and chlorine far in excess of river-water in the neighbourhood, though the strata are the same.[5] Occasionally, by constant passage of the water, a channel is formed, which may suddenly discharge into the well; and probably some of the cases of sudden poisoning from water have thus arisen.

A well drains an extent of ground about it nearly in the shape of an inverted cone. The area must depend on the soil; but the experiments at Grenelle and Passy show that the radius of the area drained is equal to four times the depth at least, and that it often exceeds this. Dupuit shows that

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1 Palmer shows this clearly in a very interesting paper in the *Indian Medical Gazette* for December 1870.

2 Much influence has been ascribed to oxidation, and doubtless in part correctly; but Dr Frankland has shown its effect to be limited. The Irwell river, after passing Manchester, runs 11 miles to its junction with the Mersey without further material pollution, and falls over 6 weirs; yet the purification by oxidation is trifling. By siphoning water from one vessel to another so as to represent a run of 96 miles, the organic carbon was only reduced 6·4 per cent. and the organic nitrogen 28·4 per cent. This, however, is widely different from running in an open river bed. Tidy's statements attribute more power to oxidation: see his pamphlet *On River Water*, also his evidence before the Royal Commission on Metropolitan Sewage Discharge.

3 In two examples of (so-called) rain-water collected in the tanks in the marsh near Tilbury Fort for the use of the troops, the solids were found to be respectively 59 and 207 parts per 100,000 (*Army Medical Reports*, vol. xvii. p. 214).

4 A good case of absorption by an open cistern of gases from water-closets and urinals is recorded by Druitt (*Medical Times and Gazette*, September 1869). The water as supplied contained ·008 parts per 100,000 of albuminoid ammonia; after absorption, 1·7 parts.

5 Roth and Lex, *op. cit.*, p. 43.

the curve of the subterranean water level rises suddenly near the well, and becomes flatter and flatter as it extends under the ground surface, the distance to which it reaches depending upon the lowering of the level of water in the well. Thus a shallow well heavily pumped may drain an area wider than a deeper well under moderate pumping. The distance of drainage area is very variable, ranging from 15 to 160 times the depression of the water in the well.[1] Professor Ansted states that the deepest (non-Artesian) well will not drain a cone which is more than half a mile in radius.

In some cases a well at lower level may receive the drainage of surrounding hills flowing down to it from great distances. Good coping stones, so as to protect from surface washings; good masonry for several feet below the surface of wells in very loose soils, so as to prevent superficial soakage, are necessary in all shallow wells.

4. *Impurities of Distribution.*

If water is distributed by hand, *i.e.*, by water-carts, barrels, or skins, there is necessarily a great chance of its being fouled. In India, where the water is generally carried by water-carriers (Bhistics), inspection of the carts or skins should be systematically made, and whenever it be possible, pipes should be substituted for the rude method of hand conveyance. But even pipes may contaminate water; metals (lead, zinc, and iron) may be partly dissolved; wood rots, and if the pipes are occasionally empty, impure air may be drawn into them, and be afterwards absorbed by the water.[2] In towns supplied on the constant system, when the pipes are becoming empty the flow of water from a tap has drawn foul water or air through a pipe at some distance, and in this way even the water of the mains has been befouled.

Coal gas passing into the ground from leaking of gas pipes sometimes finds its way into wells, or even into water pipes. In Berlin, in 1864, out of 940 public wells, 39 were contaminated by admixture with coal gas. A good instance is related by Mr Harvey,[3] where the main pipes were often empty and gas penetrated into them. Having regard to the cases in which gases from the soil (from leaking gas pipes, sewers, &c.), find their way into water pipes, it would seem important not to lay down water pipes near any other, or, what is better, have all pipes in sub-ways where they can be inspected.

SECTION III.

EFFECTS OF AN INSUFFICIENT OR IMPURE SUPPLY OF WATER.

SUB-SECTION I.—INSUFFICIENT SUPPLY.

The consequences either of a short supply of water for domestic purposes, or of difficulty in removing water which has been used, are very similar. On this point much valuable information was collected by the Health of

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[1] *Études sur le mouvement des Eaux*, par J. Dupuit; see also *Our Homes* (Cassell & Co.), 1883, p. 829.

[2] Cases of this sort are given in the *Reports of the Medical Officer of the Privy Council*, No. ii. new series. See Dr Blaxall on Fever at Sherborne, Dorset, and Dr Buchanan on the Fever at Caius College, Cambridge. In the latter case *foul trap-water* was sucked in from the closets. At Croydon, *blood* was sucked in this way from a butcher's shop.

[3] *Food, Water, and Air*, February 1872, p. 68.

Towns Commission in their invaluable Reports.[1] It was then shown that want of water leads to impurities of all kinds: the person and clothes are not washed, or are washed repeatedly in the same water; cooking water is used scantily, or more than once; habitations become dirty, streets are not cleaned, sewers become clogged; and in these various ways a want of water produces uncleanliness of the very air itself.

The result of such a state of things is a general lowered state of health among the population; it has been thought also that some skin diseases—scabies, and the epiphytic affections especially—and ophthalmia in some cases, are thus propagated. It also appears likely that the remarkable cessation of spotted typhus among the civilised and cleanly nations is in part owing, not merely to better ventilation, but to more frequent and thorough washing of clothes.

The deficiency of water leading to insufficient cleansing of sewers has a great effect on the spread of enteric fever and of choleraic diarrhœa; and cases have been known in which outbreaks of the latter disease have been arrested by a heavy fall of rain.

Little is known with certainty of the effects produced on men by deficiency in the supply of water. Under ordinary circumstances, the sensation of thirst, the most delicate and imperative of all our feelings, never permits any great deficiency for a long time, and the water-removing organs eliminate with wonderful rapidity any excess that may be taken, so as to keep the amount in the body within certain limits. But when circumstances prevent the supply of water, it is well known that the wish to drink becomes so great, that men will run any danger, or undergo any pain, in order to satisfy it. The exact bodily condition thus produced is not precisely known, but from experiments on animals and men, it would appear that a lessened amount of water in the body diminishes[2] the elimination of the pulmonary carbonic acid, the intestinal excreta, and all the important urinary excreta.

The more obvious effects produced on men who are deprived for some time of water, is besides the feeling of the most painful thirst, a great lowering of muscular strength and mental vigour. After a time exertion becomes almost impossible, and it is wonderful to see what an extraordinary change is produced in an amazingly short time if water can be then procured. The supply of water becomes, then, a matter of the most urgent necessity when men are undergoing great muscular efforts, and it is very important that the supply should be by small quantities of water being frequently taken, and not by a large amount at any one time. The restriction of water by trainers is based on a misapprehension: a little water, and often, should be the rule.

Sub-Section II.—Impure Supply.

At present, owing probably to the difficulty of making analyses of waters, the exact connection between impure water and disease does not stand on so precise an experimental basis as might be wished. There are some persons who have denied that even considerable organic or mineral impurity can be proved to produce any bad effect; while others have believed that some mineral ingredients, such as calcium carbonate, are useful.

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1 *First and Second Reports* (with evidence) *of the Health of Towns Commission*, 1844 and 1845.

2 The experiments of Falck and Scheffer on animals, and of Mosler on men and women, are here referred to.

It may be true that water containing a large quantity of organic matter, or much calcium and magnesium sulphate, has been used for long periods without any ill effects. The water of the Canal de l'Ourcq, which contains much calcium bicarbonate and some calcium and magnesium sulphate, was found by Parent-Duchâtelet to produce no bad effect, and Boudet more recently asserted the same thing.[1]

In some of these cases, however, very little careful inquiry has been made into the state of health of those using the water, and that most fallacious of all evidence, a general impression, without a careful collection of facts, has often been the only ground on which the opinion has been come to. As well observed by Sir J. Simon, in one of his philosophical Reports,[2] 'we cannot expect to find the effect of impure water always sudden and violent; its results are indeed often gradual, and may elude ordinary observation, yet be not the less real and appreciable by a close inquiry. In fact, it is only when striking and violent effects are produced that public attention is arrested; the minor and more insidious, but not less certain, evils are borne with the indifference and apathy of custom. In some cases it is by no means improbable that the use of the impure water, which is supposed to be innocuous, has been really restricted, or that experience has shown the necessity of purification in some way. This much seems to be certain, that as precise investigations proceed, and, indeed, in proportion to the care of the inquiry and the accuracy of the examination, a continually increasing class of cases is found to be connected with the use of impure water, and it seems only reasonable to infer that a still more rigid inquiry will further prove the frequency and importance of this mode of origin of some diseases.

Animal organic matter, especially when of fæcal origin; vegetable organic matter, when derived from marshes; and some salts and metals are the principal noxious ingredients.

Of the hurtful substances the suspended animal, and especially fæcal matters, are probably the worst. At least, it is remarkable how frequently, both in outbreaks of diarrhœa and enteric fever, the reports notice turbidity, discoloration, and smell of the water. It is this fact which makes the examination of colour and turbidity important. The thoroughly dissolved organic matter appears less hurtful; at least there is some evidence that perfectly clear waters, though containing much matter dissipated by heat, and consisting of dissolved organic matter or its derivatives, are often taken without injury. Probably, also, the more recent the fæcal contamination, the more injurious, since the most poisonous attacks on record have been in cases of wells into which, after slow percolation for some time, a sudden gush of sewage water has taken place.

It has been frequently stated that the readily oxidisable organic matters in water are the most dangerous. This opinion has probably arisen from the idea that a substance in rapid chemical change is more likely to excite some corresponding and hurtful action in the body; and it may be true, but there is no existing evidence which can be trusted on the point. There is, on the other hand, some evidence that animal matters forming fatty acids give rise to salts which, though not oxidising into nitrous and nitric acid, are as hurtful as the more oxidisable substances.

Of late years, too, an opinion has been expressed that the amount of the mineral substances is of little consequence. This can be true only in a

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[1] The Canal de l'Ourcq (which has a boat population of about 40,000) is to a large extent abandoned as a source of drinking water, and the greater part of Paris is supplied from the rivers Vanne and Seine. [2] *Second Annual Report to the City of London*, p. 121.

limited sense; there are some mineral substances, such as sodium chloride or carbonate, or calcium carbonate, which, within certain limits, appear to do no harm. But in the case of other minerals, such as calcium and magnesium sulphates and chlorides, and calcium nitrate, there can be little doubt that their use is injurious to many persons. It seems also probable that a combination of impurities, and especially the coexistence of organic matter and calcium sulphate, is hurtful; at least the analysis of waters which have decidedly produced injury often shows that the impurities have been numerous.

As far as at present known, the existence of *infusoria* of different kinds is not hurtful, though they may indicate by their abundance the presence of organic impurity, which they are probably useful in getting rid of. The effect of microzymes, *algæ*, or *fungi*, in drinking water is also a matter of which little or nothing is known, though it is very probable that future research may bring out something important in this direction, research which is now only in the initial stage.[1]

The most practical way of stating the facts connected with the production of disease by water will be to enumerate the diseases which have been traced to the use of impure water, and to state the nature of the impurities.

1. AFFECTIONS OF THE ALIMENTARY MUCOUS MEMBRANE.

It is reasonable to suppose that the impurities of water would be likely to produce their greatest effect upon the membrane with which they come first in contact. This is in fact found to be the case.

Affections of the Stomach—Dyspepsia.

Symptoms which may be referred to the convenient term dyspepsia, and which consist in some loss of appetite, vague uneasiness or actual pain at the epigastrium, and slight nausea and constipation, with occasional diarrhœa, are caused by water containing a large quantity of calcium sulphate and chloride, and the magnesian salts. Dr Sutherland found the hard water of the red sandstone rocks, which was formerly much used in Liverpool, to have a decided effect in producing constipation, lessening the secretions, and causing visceral obstructions; and in Glasgow, the substitution of soft for hard water lessened, according to Dr Leech, the prevalence of dyspeptic complaints. It is a well-known fact that grooms object to give hard water to their horses, on the ground that it makes the coat staring and rough—a result which has been attributed to some derangment of digestion. The exact amount which will produce these symptoms has not been determined, but water containing more than 11 parts per 100,000 of each substance individually or collectively appears to be injurious to many persons. A much less degree than this will affect some persons. In a well water at Chatham, which was found to disagree with so many persons that no one would use the water, the main ingredients were 27 parts of calcium carbonate, 16 parts of calcium sulphate, and 18·5 parts of sodium chloride in 100,000. The total solids were 71·4 parts in 100,000. In another case of the same kind, the total solids were 83 parts in 100,000: the calcium carbonate was 31, the calcium sulphate 16, and the sodium chloride 20 parts per 100,000.

[1] See G. Bischof, "On Dr R. Koch's Bacteriological Water Test," *Lancet*, April 9, 1887.

Iron, in quantities sufficient to give a slight chalybeate taste, often produces slight dyspepsia, constipation, headache, and general malaise. Custom sometimes partly removes these effects.

Diarrhœa.

Many conditions produce diarrhœa.

(*a*) *Suspended Mineral Substances.*—Clay, Marl—as in the cases of the water of the Maas, the Mississippi, the Missouri, Rio Grande, Kansas,[1] of the Ganges, and many other rivers—will at certain times of the year produce diarrhœa, especially in persons unaccustomed to the water. The hill diarrhœa at Dhurmsala is produced, apparently, by suspended very fine scales of mica.[2]

(*b*) *Suspended Animal, and especially Fœcal Matters*, have produced diarrhœa in many cases; such water always contains dissolved organic matters, to which the effect may be partly owing. The case of Croydon in 1854 (Carpenter) is one of the most striking on record. In cases in which the water is largely contaminated with suspended sewage, it is important to observe that the symptoms are often markedly choleraic (purging, vomiting, cramps, and even some loss of heat). This point has been again noticed by Oldekop of Astrachan,[3] who found marked choleraic symptoms to be produced by the water of the Volga, which is impregnated with sewage. Seven cases in one house of violent gastro-intestinal derangement (vomiting, diarrhœa, colic, and fever), produced by water contaminated by sewage which had passed into the cistern, are recorded by Dr Gibb.[4] In the prison at Halle an outbreak of diarrhœa was traced by Dolbruck to the contamination of water with putrid substances. In St Petersburg the water of the Neva, which is rich in organic substances, gives diarrhœa to strangers.[5]

Suspended animal and vegetable substances, washed off the ground by heavy rain into shallow wells, have often produced diarrhœa, as at Prague in 1860, when an endemic of "catarrh of the alimentary canal" was caused by heavy floods washing impurities into wells.[6]

(*c*) *Suspended Vegetable Substances.*—In this country, and also in the late American civil war, several instances have occurred of diarrhœa arising from the use of surface and ditch water, which ceased when wells were sunk; possibly there might be also animal contamination. It is not, therefore, quite certain that suspended vegetable matter was the *vera causa*. Surgeon-Major Gore has recorded a violent outbreak of diarrhœa at Bulama, on the west coast of Africa,[7] produced by the water of a well; the water was itself pure, but was milky from suspended matters, consisting of débris of plants, chlorophyll, minute cellular and branched *algæ*, *monads*, *polygastrica*, and minute particles of sand and clay. When filtered the water was quite harmless.

(*d*) *Dissolved Animal Organic Matter.*—The opinion is very widely diffused that dissolved and putrescent animal organic matter, to the amount of 4 to 14 parts per 100,000, may produce diarrhœa. This is possibly

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[1] Hammond's *Hygiene*, p. 218.
[2] Whitwell, *vide* Dr Macnamara's *Eighth Report on Potable Waters in Bengal*, Appendix, p. 44.
[3] Virchow's *Archiv*, band xxvi. p. 117.
[4] *British Medical Journal*, Oct. 1870.
[5] Ilisch, quoted by Roth and Lex, *Mil.-Gesundheitspfl.*, p. 24.
[6] Canstatt's *Jahresb.*, 1862, vol. ii. p. 31.
[7] Report on Hygiene by Dr Parkes, *Army Medical Report*, vol. v. p. 428.

correct, but two points must be conceded—1*st*, that there are usually other impurities which aid the action of the organic matter; and 2*nd*, that organic matter, even to the amount of 14 to 21 parts per 100,000, may exist without bad effects, if it be perfectly dissolved. In the latter case the water is, however, always clear and sparkling, never tainted or discoloured. The frequent presence of other impurities renders it difficult to assign its exact influence to dissolved organic matters.

In the case of a well-ventilated court in Coventry,[1] where diarrhœa was constantly present, the water contained 8·1 parts per 100,000 of volatile and combustible matter, but then it contained also no less than 150 parts of fixed salts, which, as the water had a permanent hardness of 74 (metrical scale) after boiling, must have consisted of calcium and magnesium sulphates and chlorides. It also contained alkaline salts, nitrates, and ammonia. The composition was therefore so complex, that it is difficult to assign to the organic matter its share in the effects.

The animal organic matter derived from graveyards appears to be especially hurtful; here also ammonium and calcium nitrites and nitrates may be present.

(*e*) *Dissolved Vegetable Matter.*—There is some evidence to show that this produces diarrhœa. Wanklyn cites the case of the Leek workhouse and also that of Biddulph Moor, in both of which vegetable matter in solution appeared to produce diarrhœa.

(*f*) *Fœtid Gases.*—Water containing much hydrogen sulphide will give rise to diarrhœa, especially if organic matter be also present. In the Mexican War (1861–62), the French troops suffered at Orizaba from a peculiar dyspepsia and diarrhœa, attended with immense disengagement of gas and enormous eructations after meals. The eructed gas had a strong smell of hydrogen sulphide.[2] This was traced to the use of water from sulphurous and alkaline springs; even the best waters of Orizaba contained organic matter and ammonia in some quantity. The experiments of Professor Weber have shown what marked effects are produced by the injection of hydrogen sulphide in solution in water into the blood; is it possible that water containing animal organic matter may occasionally form SH_2 after absorption into the blood, and that the poisonous effect of some water may be owing to this? The symptoms of poisoning by water contaminated by sewage are sometimes very like those noted by Weber in his experiments, viz., diarrhœa and even choleraic symptoms (lowering of temperature), and irritation of the lungs, spine, liver, and kidneys.

The absorption of sewer gases, as when the overflow-pipe of a cistern opens into the sewers, will cause diarrhœa. This seems perfectly proved by the case recorded by Dr Greenhow, in Sir J. Simon's second report.[3]

(*g*) *Dissolved Mineral Matters*, if passing a certain point, produce diarrhœa. Boudin refers to an outbreak of diarrhœa at Oran, in Algiers, which was distinctly traced to bad water, and ceased on the cause being removed; the composition of the water is not explicitly given, but it contained lime, magnesia, and carbonate of soda. Sulphates of lime and magnesia also cause diarrhœa, following sometimes constipation. The selenitic well waters of Paris used to have this effect on strangers. Parent-Duchâtelet[4] noticed the constant excess of patients furnished by the prison

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[1] Greenhow, *Second Report of the Medical Officer of the Privy Council*, 1860, p. 75.

[2] Poncet, in *Rec. de Mém. de Méd. Mil.*, 1863, p. 218. The exact words are "une odeur d'acid sulfurique," but "sulfhydrique" must be meant.

[3] *Second Report of the Medical Officer of the Privy Council*, Parl. Paper, 1860, p. 153.

[4] *Hygiene Publique*, t. i. p. 236.

of St Lazare, in consequence of diarrhœa, and he traced this to the water, which "contained a very large proportion of sulphate of lime and other purgative salts"; and he tells us that Pinel had noticed the same fact twenty years before in a particular section of the Salpêtriére. In some of the West Indian stations, the water drawn from the calcareous formation has been long abandoned, in consequence of the tendency to diarrhœa which it caused.

Calcium nitrate waters also produce diarrhœa. A case is on record, in which a well water was obliged to be disused, in consequence of its impregnation with butyrate of calcium (150 parts per 100,000), which was derived from a trench filled with decomposing animal and vegetable matters.[1]

Brackish water (whether rendered so by the sea, or derived from loose sands) produces diarrhœa in a large percentage of persons, and at some of the Cape frontier stations water of this character formerly caused much disease of this kind. In a water examined at Netley, which became brackish from sea water and produced diarrhœa in almost all persons, the amount of chloride of sodium was found to be 361 parts per 100,000. But, doubtless, a much less quantity than this, especially if chloride of magnesium be present, will act in this way.

(*h*) *Metallic Impregnation.*—Occasionally animal organic matter acts in an indirect way, by producing nitrites and nitrates, which act on metals.

Dr Bædeker,[2] a physician in Witten, was called to some cases of sickness produced apparently by water. On examining the point, he found the water was drawn from a pump, with a copper cylinder, and contained a considerable quantity of copper, which seemed to be in combination with some organic matter.[3] Lead (as might have been anticipated) was also largely present in this water, as leaden pumps were used; iron, on the contrary, was not dissolved.

Dysentery.

Dysentery also is decidedly produced by impure water, and this cause ranks high in the etiology of dysentery, though perhaps it is not the first.

Several of the older army-surgeons refer to this cause. Pringle does so several times, and also Donald Munro.[4] In the West Indies, Lemprière,[5] in 1799, noticed the increase of bowel complaints in Jamaica in May, when, after floods, the water was bad and turbid, "and loaded with dirt and filth." He also mentions, that at Kingston and Port Royal the dysentery was owing to brackish water. It was not, however, for many years after this that fresh sources of water were sought for in the West Indies, and that rain-water began to be used when good spring or river water could not be got.

Davis[6] mentions as a curious fact, in reference to the West Indies, that ship's crews, when ordered to Tortola, were "invariably seized with fluxes," which were caused by the water. But the inhabitants who used tank (*i.e.*,

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[1] *Zeitschrift für Hygiene*, vol. i. p. 166. See also a remark on the effect of calcium and potassium nitrate in causing a tendency to diarrhœa in the Report on the Drainage of Berlin (*Die Kanalisation von Berlin*, 1868, pp. 27, 28).

[2] Pappenheim's *Beiträge*, Heft iv. p. 49.

[3] The amount of copper required to produce poisonous symptoms appears to be doubtful. It is said that the miners in the desert of Attacama, in South America, prefer to use water containing so much copper as to have a distinct green colour, rather than the water brought up from the wells near the shore in skins, which give it an unpleasant taste. It is true that it is used for making coffee, and may thus be to a certain extent purified.

[4] *Campaigns in Flanders and Germany.*

[5] Vol. i. p. 25.

[6] *On the Walcheren Fever*, p. 10.

rain) water were free; and so well known was this, that when any resident at Tortola was invited to dinner on board a man-of-war, it was no unusual thing for him to carry his drinking water with him

The dysentery at Walcheren, in 1809, was in no small degree owing to the bad water, which was almost everywhere brackish.

The epidemic of Guadaloupe, in 1847, recorded by Cornuel, seems also quite conclusive as to the effect of impure water in causing not merely isolated cases, but a widespread outbreak.[1]

In 1860, at Prague, there were many cases of dysentery, clearly traced to the use of water of wells and springs rendered foul by substances washed into the water by heavy floods. Exact analyses were not made.

On the west coast of Africa (Cape Coast Castle), an attack of dysentery was traced by Surgeon-Major Oakes to the passage of sewage from a cesspool into one of the tanks. "This was remedied, and the result was the almost total disappearance of the disease."

That in the East Indies a great deal of dysentery has been produced by impure water, is a matter too familiar almost to be mentioned (Annesley; Twining). Its constant prevalence at Secunderabad, in the Deccan, appears to have been partly owing to the water which percolated through a large graveyard. One of the sources of water contained 170 parts per 100,000 of solids, and in some instances there were 11, 16, and even 43 parts per 100,000 of organic matter.[2]

Champouillon[3] has recorded a case in which two regiments used the impure water from the Canal de l'Ourcq, near Paris. One regiment mixed the water with coffee or red wine, the tannin of which united with the organic matter; this regiment had no dysentery. The second regiment used brandy, which precipitated the organic matter on the side of the vessel, where it putrefied. This regiment suffered from dysentery; the substitution of red wine for brandy stopped the disease.

The great effect produced by the impure water of Calcutta in this way has been pointed out by Chevers.[4]

In time of war this cause has often been present; and the great loss by dysentery in the Peninsula, at Ciudad Rodrigo, was partly attributed by Sir J. M'Grigor to the use of water passing through a cemetery where nearly 20,000 bodies had been hastily interred.

The impurities which thus produce dysentery appear to be of the same kind as those which cause the allied condition, diarrhœa. Suspended earthy matters, suspended animal organic matter, calcium and magnesium sulphates and chlorides, calcium and ammonium nitrates, large quantities of sodium and magnesium chlorides in solution, appear to be the usual ingredients; but there are few perfect analyses yet known.[5]

The observations which prove so satisfactorily that the dysenteric stools can propagate the disease, make it probable that, as in the case of enteric fever and cholera, the accidental passage of dysenteric evacuations into drinking water may have some share in spreading the disease.

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1 See a review by the late Dr Parkes on Dysentery, in the *British and Foreign Medical and Chirurgical Review* for 1847, for fuller details of this epidemic.

2 *Indian Report*, p. 44.

3 *Rec. de Mém. de Méd. Mil.*, 1872, Sept., p. 230.

4 *Indian Annals*, No. 17, p. 70, 1864.

5 A localised epidemic of dysentery occurred in some barracks at Nürnberg in the summer of 1872, 30 cases and 4 deaths taking place among the soldiers. The absorption of putrefaction gases from the cloaca in the wings of the building by the drinking water, was considered to be the cause; the water contained nitrates and free ammonia. An individual predisposition to the disease appeared, however, to be also necessary (Schmidt's *Jahrbücher*, 1874, vol. i. p. 25).

2. AFFECTION OF OTHER MUCOUS MEMBRANES BESIDES THE ALIMENTARY.

Little has yet been done to trace out this point. At Prague, after the severe flood of 1860, bronchial catarrh was frequent, probably caused chiefly by the chills arising from the great evaporation; but it was noticed that bronchial catarrh was most common when the drinking water was foulest and produced dysentery. Possibly the bronchial and the urinary mucous membranes may also suffer from foul water; the point is well worthy of close investigation.

3. SPECIFIC DISEASES.

That some of the specific diseases are disseminated by drinking water is a fact which has only attracted its due share of attention of late years. It is certainly one of the most important steps in etiology which has been made in this century, and the chief merit of its discovery is due to the late Dr Snow.

Malarious Fevers.

Hippocrates states that the spleens of those who drink the water of marshes become enlarged and hard; and Rhazes not only asserted this, but affirmed that it generated fevers. Little attention seems to have been paid to this remark, and in modern times the opinions of Lancisi, that the air of marshes is the sole cause of intermittents, has been so generally adopted, that the possibility of the introduction of the cause by means of water, as well as of air, was overlooked. Still, it has been a very general belief among the inhabitants of marshy countries that the water could produce fever. Henry Marshall[1] says that the Singhalese attribute fevers to impure water, "especially if elephants or buffaloes have been washing in it," and it is to be presumed that he referred to periodical fevers. On making some inquiries of the inhabitants of the highly malarious plains of Troy during the Crimean war, Dr Parkes found the villagers universally stated, that those who drank marsh water had fever at all times of the year, while those who drank pure water only got ague during the late summer and autumnal months. The same belief is prevalent in the south of India; and in Western Candeish, Canara, Balaghut, and Mysore, and in the deadly Wynaad district, it is stated by Mr Bettington, of the Madras Civil Service, that it "is notorious that the water produces fever and affections of the spleen." The essay by this gentleman[2] gives, indeed, some extremely strong evidence on this point. He refers to villages placed under the same conditions as to marsh air, but in some of which fevers are prevalent, in others not; the only difference is, that the latter are supplied with pure water, the former with marsh or nullah water full of vegetable débris. In one village there were two sources of supply—a tank fed by surface and marsh water, and a spring; those only who drank the tank water got fever. In a village (Tulliwaree) no one used to escape the fever; Mr Bettington dug a well, the fever disappeared, and, during fourteen years, had not returned.

Another village (Tambatz) was also "notoriously unhealthy"; a well was dug, and the inhabitants became healthy. Nothing can well be stronger than the positive and negative evidence brought forward in this paper.

Dr Moore[3] also noted his opinion of malarious disease being thus produced; and M. Commaille[4] has since stated, that in Marseilles paroxysmal

[1] *Topography of Ceylon*, p. 52.
[2] *Indian Annals*, 1856, p. 526.
[3] *Indian Annals*, 1867.
[4] *Rec. de Mém. de Méd. Mil.*, Nov. 1868, p. 427.

fevers, formerly unknown, have made their appearance, since the supply to the city has been taken from the canal of Marseilles. In reference also to this point, Dr Townsend, the Sanitary Commissioner for the Central Provinces in India, mentions in one of his able reports[1] that the natives have a current opinion that the use of river and tank water in the rainy season (when the water always contains much vegetable matter) will almost certainly produce fever (*i.e.*, ague), and he believes there are many circumstances supporting this view. In this way the prevalence of ague in dry elevated spots is often, he thinks, to be explained. He mentions also that the people who use the water of streams draining forest lands and rice fields "suffer more severely from fever (ague) than the inhabitants of the open plain drawing their water from a soil on which wheat grows." In the former case there is far more vegetable matter in the water. The Upper Godavery tract is said to be the most aguish in the province, yet there is not an acre of marshy ground; the people use the water of the Godavery, which drains more dense forest land than any river in India.

In the "Landes" (of south-west France), the water from the extensive sandy plain contains much vegetable matter, obtained from the vegetable deposit, which binds together the siliceous particles of the subsoil. It has a marshy smell, and, according to Fauré, produces intermittents and visceral engorgements. Dr Blane, in his papers on Abyssinia, mentions that on the march from Massowah to the Highlands, Mr Prideaux and himself, who drank water only in the form of tea or coffee, entirely escaped fever, while the others who were less careful suffered, and, as Dr Blane believes, from the water.

The same facts have been noticed in this country. Many years ago Mr Blower of Bedford mentioned a case in which the ague of a village had been much lessened by digging wells, and he refers to an instance in which, in the parish of Houghton, almost the only family which escaped ague at one time was that of a farmer who used well-water, while all the other persons drank ditch water.[2]

At Sheerness the use of the ditch water, which is highly impure with vegetable débris, has been also considered to be one of the chief causes of the extraordinary insalubrity.[3]

At Versailles a sudden attack of ague in a regiment of cavalry was traced to the use of surface water taken from a marshy district.[4]

The case of the "Argo," recorded by Boudin,[5] is an extremely strong one. In 1834, 800 soldiers in good health embarked in three vessels to pass from Bona in Algiers to Marseilles. They all arrived at Marseilles the same day. In two vessels there were 680 men without a single sick man. In the third vessel, the "Argo," there had been 120 men; thirteen died during the short passage (time not given), and of the 107 survivors no less than 98 were disembarked with all forms of paludal fevers, and as Boudin himself saw the men, there was no doubt of the diagnosis. The crew of the "Argo" had not a single sick man.

All the soldiers had been exposed to the same influences of atmosphere before embarkation. The crew and the soldiers of the "Argo" were ex-

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1 For 1870, published at Nagpore in 1871, para. 143 *et seq.*
2 Snow *On the Mode of Communication of Cholera*, 2nd edit., 1855, p. 130.
3 Is it not possible that the great decline of agues in England is partly due to a purer drinking water being now used? Formerly, there can be little doubt, when there was no organised supply, and much fewer wells existed, the people must have taken their supply from surface collections and ditches, as they do now, or did till lately, at Sheerness.
4 Grainger's *Report on Cholera*, Appendix (B), page 95; footnote.
5 *Traité de Géographie et de Statistique Médicales*, 1857, t. i. p. 142.

posed to the same atmospheric condition during the voyage; the influence of air seems therefore excluded. There is no notice of the food, but the production of malarious fever from food has never been suggested. The water was, however, different—in the two healthy ships the water was good. The soldiers on board the "Argo" had been supplied with water from a marsh, which had a disagreeable taste and odour; the crew of the "Argo" had pure water. The evidence seems here as nearly complete as could be wished.[1]

One very important circumstance is the rapidity of development of the malarious disease and its fatality when introduced in water. It is the same thing as in the case of diarrhœa and dysentery. Either the fever-making cause must be in larger quantity in the water, or, what is equally probable, must be more readily taken up into the circulation and carried to the spleen, than when the cause enters by the lungs.

In opposition, however, to all these statements must be placed a remark of Finke's,[2] that in Hungary and Holland marsh water is daily taken without injury. But in Hungary, Dr Grosz states that, to avoid the injurious effects of the marsh water, it is customary to mix brandy with it, "a custom which favours hypertrophies of the internal organs."[3] Professor Colin, of the Val de Grâce, who is so well known for his researches on intermittent fever,[4] is also inclined to question the production of paroxysmal fevers by marsh water. He cites numerous cases in Algiers and Italy, where impure marsh water gave rise to indigestion, diarrhœa, and dysentery, but in no case to intermittent fever, and in all his observations he has never met with an instance of such an origin of ague. He therefore denies this power, and in reference to the celebrated case of the "Argo," without venturing to contest it, he yet views it with suspicion, and questions whether Boudin has given the exact details.

An instructive case, however, is recorded by Brigade-Surgeon Faught.[5] The artillery quartered at Tilbury Fort (in the Gravesend district) have generally suffered more or less from ague, whilst the people at the railway station, and the coastguard and their families in the ship lying just outside the fort, never suffer from malarious poisoning. The troops have been supplied with drinking water from two underground tanks which receive rain-water from the roof of the barracks, whilst the other persons above mentioned draw their drinking-water from a spring near the railway station. From December 1873 to July 1874 the troops were supplied from the same source, on account of the barrack tanks being out of repair. The table on page 64 shows the returns of sickness.

Another case of importance is that recounted by C. Smart, Capt. and Assist. Surg., U.S.A.[6] In the Rocky Mountain district of North America a fever prevails, which is popularly known as the *Mountain fever;* it is evidently malarious, and is amenable to quinine. There is, however, no malarious district in the neighbourhood, and cases of intermittent fever from the plains recover rapidly there, and the disease occurs sometimes when the thermometer is at times below zero, and always below the freezing-point, but most frequently at times when fever does not occur in the plains, but which coincide with the melting of the snows, viz., May, June, and July. Dr Smart found that all the water in the rivers contained

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[1] Ritter, *Hirsch in Jahresb. für gen. Med. for* 1869, p. 192.
[2] Oesterlen's *Handb. der Hygiene*, 2nd edit., 1857, p. 129; footnote.
[3] Quoted by Wutzur, *Reise in dem Orient Europas*, band i. p. 101.
[4] *De l'Ingestion des eaux Marécageuses comme cause de la Dysentérie et des Fièvres Intermittentes*, par L. Colin, Paris, 1872.
[5] *Army Medical Reports*, vol. xvii. p. 212.
[6] For details see *A.M.D. Reports*, vol. xix. p. 190.

a large excess of organic matter, the purest showing from 0·019 to 0·028 per 100,000 of albuminoid ammonia, whilst the springs showed only 0·010. The amount was much increased after heavy snow-fall, and on analysing the snow he was surprised to find it contained a large excess of organic matter, especially that which fell in large heavy flakes (as high sometimes as 0·058 of albuminoid ammonia). Dr Smart concludes that vegetable organic matter is blown up from the plains and precipitated with the snow, and, when the latter melts, carried into the streams. At stations where care is taken with the water-supply, and especially where suspended matter is prevented as much as possible from getting into the water, the disease is slight.[1]

FEVER AT TILBURY FORT.

Date.	Strength.	Admissions for Ague.	Percentage of Admissions.	Ratio of Admissions per annum.	Water used.	
1872. Jan. to June.	103	34	33	66	Water from barrack tanks.	The analyses of the waters showed that the tanks were exposed to soakage from the surrounding salt marsh, for the so-called rain-water yielded 59 parts per 100,000 of total solids in the one case, and 207·5 in the other, the chlorine being respectively 18 and 47. The station water gave 54·3 total solids and only 4·7 of chlorine. As regards organic matter, the tank waters showed actually less impurity than the station water by the ammonia method, but by the permanganate method they were three times as impure. For full details and for the microscopic examination, see the original paper.
1873. Jan. to June.	102	12	11·8	23·6	Do.	
1873–4. Dec. 1873 to July 1874.	90	1*	1·1	1·9	Water from spring at the railway station.	
1874–5. Nov. 1874 to March 1875.	53	4†	7·6	22·8	Water from barrack tanks.	

* This case was in hospital only five days ; it occurred only a few days after the arrival of the battery.

† None of these had ever had ague before ; two had to be sent on furlough, being much debilitated by malaria.

W. North[2] thinks that "proof that the malarial affection can be conveyed by water is wanting, though very largely credited by the natives of countries where the disease prevails." As yet the views of Klebs and Tommasi-Crudeli have not been confirmed.

[1] In my Report on Hygiene, *A.M.D. Reports*, vol. xviii., an analysis is given of the water of the Rakus Tal Lake, on the northern side of the Himalayan range, the sample having been brought home by Lieut.-Col. H. Knight, late 19th Regiment of Foot. In this water the saline ammonia was 0·056 and the albuminoid 0·070 per 100,000. Contrast this with Loch Katrine and other lakes in this country, where the respective amounts are under 0·002 and 0·005, and we have a difference which requires explanation. May it not be that in this country we have so much less snow as a feeder of our mountain lakes, and also fewer districts from which winds could carry up organic matter ?—[F. de C.]

[2] *Op. cit.*

Enteric Fever.

The belief that enteric fever can spread by means of water as well as air appears to be quite of modern origin, though some epidemics, such as the "Schleim-fieber" of Göttingen in 1760, were attributed in part to the use of impure water. In 1822, Walz, at Saarlouis, in 1843, Müller, at Mayence, and in 1848, E. A. W. Richter, at Vienna, published cases illustrative of this.[1] In 1852 Dr Austin Flint[2] published the particulars of a similar outbreak of enteric fever at the hamlet of North Boston (Erie, U.S.) in 1843.

In 1852-53 a severe outbreak of enteric fever took place at Croydon, and was thoroughly investigated by many competent observers; and it was shown by Dr A. Carpenter that it was partly, at any rate, spread by the pollution of the drinking water from the contents of cesspools.

In 1856 Dr Routh,[3] and in 1859 Dr W. Budd,[4] published very conclusive cases. The latter had long been convinced of the *occasional* propagation of enteric fever in this way.

In 1860 an outbreak of enteric fever occurred at the convent of Sisters of Charity at Munich. 31 persons out of 120 were attacked between 15th September and the 4th of October with severe illness, and 14 of these cases were true enteric; 4 died. The cause was traced to wells impregnated with much organic matter (and among other things enteric dejections), and containing nitrates and lime. On the cessation of the use of this water the fever ceased.[5]

The propagation of enteric fever in Bedford would certainly appear, from Sir J. Simon's report,[6] to have been partly through the medium of the water. Dr Schmitt[7] has for several years paid particular attention to this point, and in 1861 published several very striking cases.

A case bearing on the same point was brought before the Metropolitan Officers of Health in 1862[8] by Mr Wilkinson of Sydenham. In this case the water was contaminated by absorption of sewer gases.

In 1862 a very sudden and severe outbreak of enteric fever in a barrack at Munich was traced to water impregnated with fæcal matter;—on ceasing to use the water, the disease disappeared.[9] In 1865 a very remarkable outbreak of enteric fever occurred at Ratho, in Scotland, and was traced to drinking water contaminated with sewage.[10] In 1866 enteric fever broke out in a girls' school at Bishopstoke, near Southampton, and was traced unequivocally to the bursting of a sewer pipe into the well. The water was disagreeable both to smell and taste. 17 or 18 persons were affected out of 26 or 28. Several very striking instances are recorded in Sir J. Simon's

[1] All these cases are related by Riecke in his excellent work, *Der Kriegs und Friedens-Typhus*, Nordhausen, 1850, pp. 44-58.

[2] *Clinical Reports on Continued Fever*, by Austin Flint, M.D., Buffalo, 1852, p. 380.

[3] *Fæcal Fermentation as a Cause of Disease.* Pamphlet. Lond. 1856, p. 34.

[4] *Lancet*, Oct. 29, 1859, p. 432.

[5] *Edinburgh Medical Journal*, Jan. 1862, p. 1153; see also Gietl, *Die Ursachen des Enter. Typhus in München*, 1865, p. 58.

[6] *Third Report of the Medical Officer of the Privy Council*, 1860.

[7] *Journ. de Méd. de Bruxelles*, Sept. 1861; and Canstatt's *Jahresb.* for 1861, band iv. pp. 182, 183. See the 2nd edition of this work for a short account of them.

[8] *British Medical Journal*, March 1, 1862.

[9] Gietl, *Die Ursachen des Ent. Typhus in München*, 1865, p. 62. In this little book is much evidence to show the propagation of enteric fever by foul water and by deficient arrangements for removal of excreta, as well as many instances of the carrying of the disease from place to place, analogous to those narrated by Bretonneau many years ago.

[10] *Edin. Med. Journ.*, Dec. 1865. In this case a groom came to the house ill with enteric fever from Dundee, and thus introduced the disease.

Reports by Drs Seaton, Buchanan, and Thorne,[1] and in some of these cases analyses of the water were made which showed it to be impure, and to contain organic sewage or its derivatives. A very good case, at the Garnkirk works in Glasgow, is recorded by Dr Perry.[2] Dr De Renzy, the Sanitary Commissioner of the Punjab, has also published a remarkable paper on the extinction of enteric fever in Millbank prison, and shows, from the statistics of many years, that the fever has entirely disappeared since the use of Thames water was given up; the disappearance was coincident with the change in the water supply. Two excellent cases are recorded by Dr Clifford Allbutt[3] and one by Dr Wohlrab, which are free from ambiguity.[4] A very good case is recorded by Dr Latham.[5] Enteric fever was introduced into a village, and spread by the agency of contaminated drinking water.[6]

A destructive outbreak took place at Caterham and Redhill during 1878. This was investigated by Dr Thorne Thorne, who traced it to contamination of the water-supply by the stools of a workman suffering from mild enteric fever, who was employed in the Company's wells. The disease was confined to those who consumed the water, and ceased after the wells were pumped out and cleansed. The inmates of the Lunatic Asylum and the detachment of troops at Caterham barracks used the water from the asylum well, and did not suffer.[7]

That water may be the medium of propagating enteric fever thus seems to be proved by sufficient evidence; and it has been admitted by men who have paid special attention to this subject, as Jenner, W. Budd, and Simon.

Two questions arise in connection with this subject—

1. As enteric fever undoubtedly spreads also through the air, What is the proportion of cases disseminated by water as compared with those disseminated by air? No answer can yet be given to this question.[8]

There is one point of some interest. When the dates of attack are given, it is curious to observe how short the incubative period appears to be; while it is probable that it takes many days (8 to 14) after the enteric poison has entered with the air before the early malaise comes on—in some of the cases of enteric fever brought on by water, two or three days only elapse before the symptoms are marked.[9]

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[1] Dr Seaton's Report on Tottenham (*Report of Medical Officer to the Privy Council for* 1866, p. 215); Dr Buchanan on Guildford (*Ibid.* for 1867, p. 34); Dr Thorne's Report on Terling (*Ibid.*, p. 41); Dr Buchanan's Report on Wicken-Bonant (*12th Report*, p. 72). In all these instances the evidence reaches the highest degree of probability, and in the cases of Guildford and Wicken-Bonant of almost absolute certainty. See also Report on Sherborne by Dr Blaxall; on Caius College, Cambridge, by Dr Buchanan (both in No. ii. new series); on Lewes, by Dr Thorne (No. iv. new series); also the case of Over-Darwen (*Sanitary Record*, 1875); case given by Dr Stallard (*Lancet*, Feb. 1872); Dr Barclay's Reports on Bangalore (*Army Med. Reports*, vol. xiii. p. 208). Geissler also quotes from Hägler a very strong case occurring at Lausen (Schmidt's *Jahrb.* 1874, No. 2, p. 185).

[2] *Lancet*, June 1868.

[3] See Report on Hygiene, *Army Med. Dept. Blue Book*, 1860, p. 23.

[4] *Archiv der Heilk.*, vol. xii. p. 134 (1871).

[5] *Lancet*, July 15, 1871.

[6] A remarkable case is reported by Dr Zuckschwerdt occurring in the orphan asylum at Halle in 1871. Also by Dr Burkart at Stuttgart, at Reinhartsdorf in Switzerland, and at Schandau, all distinctly traceable to impure water (Schmidt's *Jahrbücher*, 1874).

[7] See Report by Dr Thorne; also *A.M.D. Reports*, vol. xx. p. 222.

[8] Sir J. Simon, in his second Report, new series, gives a table of 146 outbreaks investigated by his officers in 1870-3 (4 years), in all of which great excremental pollution of air or water, or generally of both, was found. Biermer, from an analysis of 1300 cases, cites evidence of water carriage (Schmidt's *Jahrb.*, 1873, No. 8. p. 195).

[9] Dr W. Budd says, in a letter to the late Dr Parkes,—"In the cases in which the poison is conveyed by water, infection seems to be much more certain; and I have reason to think that the period of incubation is materially shortened. An illustration of this seems to be furnished by the memorable outbreak which occurred at Cowbridge some years ago, and which presented

A very large number also of the susceptible persons who drank the water are affected.

2. Will decomposing sewage in water produced enteric fever, or must the evacuations of an enteric patient pass in? This is part of the larger question of the origin and propagation of specific poisons. It is certainly remarkable, in the range of cases recorded by Schmitt, how uniformly the possibility of the passage of enteric stools is disregarded. Everything is attributed to fæcal matters merely. A case recorded by Dr Downes,[1] in which six cases of enteric fever resulted from the overflow of non-enteric sewage into a well, supports this view. On the other hand, in the cases recorded by Allbutt and Wohlrab already referred to, contaminated water had been used for some time without producing enteric fever. Persons affected with enteric fever then entering the place, their discharges passed into the drinking water, and then an outbreak of enteric fever followed. An extremely strong case is given by Ballard.[2] Very polluted water had been used for years by the inhabitants of the village of Nunney without causing fever, when a person with enteric fever came from a distance to the village, and the excreta from this person were washed into the stream supplying the village. Between June and October 1872 no less than 76 cases occurred out of a population of 832 persons. All those attacked drank the stream water habitually or occasionally. All who used filtered rain or well water escaped, except one family who used the water of a well only 4 or 5 yards from the brook. The case seems quite clear—first, that the water caused the disease; and secondly, that though polluted with excrement for years, no enteric fever appeared until an imported case introduced the virus. Positive evidence of this kind seems conclusive, and we may now safely assume that the presence of enteric evacuations in the water is necessary. Common fæcal matter may produce diarrhœa, which may perhaps be febrile,[3] but for the production of enteric fever the specific agent must be present. The opinion that the stools of enteric fever are the special carriers of the poison was first explicitly stated by Canstatt,[4] and was also ably argued by W. Budd.

Cholera.

Few of the earlier investigators of cholera appear to have imagined that the specific poison might find entrance by the means of drinking water. There is an intimation of the kind in a remark by Dr Müller;[5] and Jameson [6] alludes to the effect of impure water, but in a cursory way.

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this unexampled fact, that out of some 90 or 100 persons who went to a race ball at the principal inn there, more than one-third were within a short time laid up with fever. In this case there was satisfactory reason to think that the water was contaminated, though there was no chemical examination." In the attack at Guildford, however, the incubative period was not shortened, as Dr Buchanan calculates it at 11 days; neither was it shortened at Caterham.

[1] *Lancet*, 27th April 1872.

[2] *Report to the Local Government Board* on an outbreak of enteric fever at Nunney, Sept. 1872.

[3] A good instance is given by Mr R. Bond-Moore (*London Medical Record*, May 27, 1874, page 327), as occurring at Sedgely Park School. Two years previously the water supply became contaminated with ordinary sewage, but no enteric fever resulted, although there was diarrhœa, sickness, great languor, and great prostration. The leaking drain was repaired, and the attack ceased. Two years after enteric fever was introduced by one of the boys, and spread apparently by the use of the closets.

[4] "Wahrscheinlich sind die Exhalationen des Krankes, seine Excremente, *vielleicht die typhösen Aftergebilde im Darme*, die Träger des Contagiums."—Canstatt, *Spec. Path. und Ther.*, 2nd edit. band ii. p. 582 (1847).

[5] *Einige Bemerkungen über die Asiat. Cholera*, Hanover, 1848, p. 36.

[6] *Bengal Report* of 1820.

In 1849 the late Dr Snow, in investigating some circumscribed outbreaks of cholera in Horsleydown, Wandsworth, and other places, came to the conclusion that, in these instances, the disease arose from cholera evacuations finding their way into the drinking water. Judging from the light of subsequent experience, it now seems extremely probable that this was the case, and to Dr Snow must certainly be attributed the very great merit of discovering this most important fact. At first, certainly, the evidence was defective,[1] but gradually fresh instances were collected, and in 1854 occurred the celebrated instance of the Broad Street pump in London, which was investigated by a committee, whose report, drawn up by Mr John Marshall, of University College, with great logical power, contains the most convincing evidence that, in that instance at any rate, the poison of cholera found its way into the body through drinking water.[2]

In 1855 Dr Snow published a second edition of his book, giving an account of all the cases hitherto known, and adding some evidence also as to the introduction in this way of other specific poisons.[3]

The facts, at present, may be briefly summed up as follows:—

1. Local outbreaks, in which contamination of the drinking water was either proved or in which the evidence of the origin and succession of cases seemed to make it certain that the cause was in the drinking water. In England, Dr Snow and others have thus recorded cases occurring in 1849 and 1854 at Horsleydown, Broad Street, Wandsworth, West Ham, &c. In 1865 the important outbreak at Newcastle-on-Tyne,[4] when all the circumstances pointed very strongly to the influence of the impure Tyne water. In 1865 occurred the remarkable and undoubted case of water-poisoning at Theydon Bois, recorded by Mr Radcliffe,[5] and in the following year the violent outbreak in the East of London was supposed to be connected with the circulation of impure water by the East London Water Works Company. Much discussion has taken place as to the real influence of the impure water, which it is admitted on all hands was used. Mr Radcliffe[6] and Dr Farr[7] collected the evidence in favour of the opinion that the sudden outburst was really owing to this water; while Dr Letheby and some others expressed doubts on this point, chiefly on account of the difficulty of reconciling with the hypothesis certain exceptional cases both of immunity and of attack. The evidence in favour of the water being the cause appears extremely strong, and far greater difficulty arises if that view is not received than is caused by the exceptional cases referred to, of which we may not know all the particulars. In the same year (1866) an apparently unequivocal case of production of

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1 There seemed at once an *a priori* argument adverse to this view, as, at that time, all evidence was against the idea of cholera evacuations being capable of causing the disease. They had been tasted and drunk (in 1832) by men, and been given to animals, without effect. Persons inoculated themselves in dissections constantly, and bathed their hands in the fluids of the intestines; in India the pariahs who remove excreta, and everywhere the washerwomen who washed the clothes of the sick, did not especially suffer. And to these arguments must be added the undoubted fact that there were serious deficiencies of evidence in Dr Snow's early cases. (See review of Dr Parkes in the *British and Foreign Medical Chirurgical Review*, April 1855).

2 *Report on the Cholera Outbreak in St James's, Westminster, in* 1854, London. Churchill, 1855. Every point is discussed in this Report with a candour and precision which leaves nothing to be desired. For further evidence on this outbreak see *Indian Sanitary Report:* evidence of Dr Dundas Thomson, p. 272.

3 *On the Mode of Communication of Cholera*, by John Snow, M.D. London, Churchill, 2nd edition, 1855.

4 For full particulars see Dr Farr's *Report on Cholera in England*, 1866, p. 33.

5 *Report of the Medical Officer to the Privy Council for* 1865 (Eighth Report), p. 438.

6 *Report of the Medical Officer to the Privy Council for* 1866, p. 266.

7 *Report on the Cholera Epidemic of* 1866 *in England*. Supplement to the 29*th Annual Report of the Registrar-General*, 1868.

cholera by the drinking of water of a tank on board a steamer occurred at Southampton.[1]

A very striking case at Utrecht is noticed by Snellen, and is given by Dr Ballot of Rotterdam, who has adduced much strong evidence on the influence of the foul water in Holland in spreading cholera.[2]

During the epidemic in 1866, except in the East London case, no such striking instances of local outbreak from water contamination were recorded as in 1849, but there were in some parts, and especially in Scotland, as noticed by Dr Stevenson Macadam,[3] very striking coincidences between the abatement of the disease and the introduction of a fresh and pure supply.

In Germany choleraic water-poisoning has not only been less noticed, but the great authority of Pettenkofer is against its occurrence. At Munich, Pettenkofer[4] could find no evidence whatever in favour of the spread by water, nor does he consider that any further evidence was furnished by the epidemics in Germany in 1873–74.[5] Even Hirsch, who was favourable to the water theory, expresses himself with considerable caution;[6] and Günther, in his careful work on Cholera in Saxony,[7] asserts that no influence whatever was exerted by drinking water. No evidence could be obtained either in Baden or in villages near Vienna.[8] And as in all cases the observers were not only quite competent, but were fully cognizant of the opinions held in England, this negative evidence is of great weight. At the same time, it cannot be allowed to outweigh the English cases, and, moreover, even in Germany some positive evidence has been given. Dr Richter[9] attributes a preponderant influence in a local outbreak among the workmen of a sugar manufactory to the pollution of the drinking water by sewage; and a still more striking case is recorded by Dr Dinger,[10] in which the discharges of a cholera patient passed into a brook, in which also the clothes were washed; the water of this brook being used for drinking, there was a sudden and very fatal outbreak affecting the persons who took the water.

In India the evidence for cholera water poisoning has now become very strong. The great cholera outbreak of 1860 and 1861 was attributed by some medical officers to the defilement of the tank water "into which the general ordure of the natives is washed during the rainy season;"[11] and still more recently, what appears to be a striking instance has occurred. No one can read the able account given by Dr Cuningham and Dr Cutliffe[12] of the appearance of cholera among the vast crowd of pilgrims after the great bathing day at Hurdwar, without coming to the conclusion that it was a case of water-poisoning on a gigantic scale. Cholera broke out again at Hurdwar in 1879 (the pilgrimage takes place every twelve years), but in

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[1] *Report of Medical Officer to Privy Council for* 1866, p. 244. In this case the water was foul tasted, and was certainly contaminated with sewage.

[2] *Medical Times and Gazette*, May 1869. Thus it was found that those who drank the water of the Polders (reclaimed lands) died at the rate of 17·7 per 100; those who drank the well-water, 16·8 per 1000; those who drank river-water, 11·9 per 1000; those who drank rain-water filtered, only 5·3 per 1000. The city of Amsterdam itself, supplied by an aqueduct with rain-water from the downs near Haarlem, had only 4 per 1000. In Rotterdam, during the epidemic, the mortality fell to one-half immediately on pure water being supplied in the streets. (See paper by J. C. Jäger).

[3] *Transactions of the Royal Scottish Society of Arts*, vol. vii. p. 341 (1867).

[4] *Zeitsch. für Biol.*, band i. p. 353.

[5] *Ueber Cholera und deren Beziehung zur parasitären Lehre*, von Max von Pettenkofer, 1880.

[6] *Bericht der Commission des Deutschen Reiches*, heft i. saite 13.

[7] *Die Indische Cholera in Sachsen im Jahre* 1865, p. 125.

[8] Volz and Witlacil, quoted by Hirsch in *Jahresb. der gen. Med. for* 1867, band ii. p. 221.

[9] *Archiv der Heilk.*, 1867, p. 472.

[10] *Archiv der Heilk.*, 1867, p. 84.

[11] M'William, *Epidem. Society Trans.*, vol. i. p. 274.

[12] *Report of the Sanitary Commissioner with the Government of India for* 1867, Calcutta, 1868.

his report on this epidemic Dr J. M. Cuningham endeavours to throw doubts upon the propagation by means of water. The circumstances, however, were very similar in the two cases.[1] Drs T. Lewis and Douglas Cunningham discredit the influence of water;[2] and Dr D. Cunningham says:[3]—"One point seems worthy of remark, and that is, that there is no evidence of the existence of any common condition affecting local sources of water supply, and simultaneously affecting the prevalence of cholera and bowel-complaints."

That in India, however, the cholera poison is often carried by water appears probable, not only from the Hurdwar outbreaks, but from the very sudden and violent outbreaks and the great sewage contamination in the water of many districts.[4]

In Central India Dr Townsend[5] has given strong reasons for believing that the cholera of 1868–69 was, to a large extent, dependent on water-fouling. Dr Macnamara[6] has given some good evidence on the same side, and Dr Cleghorn[7] has noted some striking proofs of the same fact.

See also the remarkable case of the Yerrauda gaol, reported by Surgeon-Major H. Blanc. Out of 1279 prisoners there were 24 cases of cholera in 5 days, with 8 deaths. Of those, 22 cases occurred among 134 prisoners employed as a road-gang, and only 2 among all the others variously employed. It was shown that the road-gang alone drank of water from the Mootla River, a little below the spot where the clothes of two cholera patients from the village had been washed and their bodies burned a few days before. The rest of the prisoners drank the usual water supply laid on from a lake near Poonah. In the two cases among those otherwise employed direct infection was undoubted in one, as he attended on cholera patients, and, contrary to orders, took his meals in the cholera ward, and drank water that had been standing there; the other man slept near one of the first cases, the patient vomiting in his immediate vicinity.

Dr M. C. Furnell, Sanitary Commissioner of Madras, points out the immunity of Madras from cholera since the new water supply was obtained from the Red Hills, the same immunity extending to the districts using the water, whereas other places which do not use it still suffer from the disease. Guntur always suffered from cholera up to 1868, since which time it has been practically free, following the greater care for the water supply begun by Dr Biggwither and carried out by Dr Tyrrell.[8] A remarkable case is recorded by the Rev. J. Delpech, at Vadakencoulam.[9] Cholera was confined to the higher castes, who drank of a particular well exposed to contamination. Among the lower castes none suffered, except one woman who washed for the higher caste women. The lower caste people drank from other wells, which were less exposed to pollution.

So also in other countries; in the attack which caused such losses to the French Division in the Dobrudscha in 1855, when the wells were supposed to be poisoned, and to the English cavalry at Devna,[10] the water was apparently the means of carrying the disease.

In evidence of this kind, we must remember that each successive

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1 See section vi. of the *Sixteenth Annual Report of the Sanitary Commissioner with the Government of India*, 1880.

2 *Cholera in Relation to Certain Physical Phenomena.*

3 *Medico-Topographical Report on Calcutta.*

4 Vide *Report on the Sanitary Administration of the Punjaub for* 1867, and subsequent years, by A. C. C. De Renzy, Esq. (Cases of Peshawur and Amritzur).

5 *Report on Cholera in the Central Provinces.*

6 On *Asiatic Cholera*, see pp. 328 *et seq.*

7 *Indian Medical Gazette*, March 1872.

8 *Indian Medical Gazette*, April 1882.

9 *Indian Medical Gazette*, Dec. 1, 1879.

10 MS. essay of Dr Cattell.

instance adds more and more weight to the instances previously observed, until, from the mere accumulation of cases, the cogency of the argument becomes irresistible.

2. The evidence derived from such local outbreaks is supported by that drawn from the history of more general attacks, in which districts supplied with impure water by a water company have suffered greatly, while other districts in the same locality, and presenting otherwise the same conditions, were supplied with pure water, and suffered very little. Thus the Registrar-General has shown that the districts supplied in 1853, part by the Lambeth Company with a pure water, and part by the Southwark Company with an impure water, suffered much less than the districts supplied by the latter company alone (the proportion was 61 and 94 cases respectively to 100,000 of population). Schiefferdecker, in Königsberg, has also given evidence to show the different extent in which districts in the same city supplied with pure and impure water suffer.[1]

In Berlin, in 1866, in the houses supplied with good water the number of houses in which cholera occurred was 36·6 per cent.; in the houses with bad water, 52·3 per cent.[2]

3. Additional arguments can be drawn from instances in which towns which could not have had water contaminated with sewage have escaped, and instances in which towns which have suffered severely in one epidemic have escaped a later one, the only difference being that, in the interval, the supply of water was improved. Exeter, Hull, Newcastle-on-Tyne, Glasgow, and Moscow are instances of this. Two very good cases are related by Sir H. Acland.[3] The parish of St Clement was supplied in 1832 with filthy water from a sewer-receiving stream. In 1849 and 1854 the water was from a purer source. In the first year, the cholera mortality was great; in the last years, insignificant. In Copenhagen a fresh water supply was introduced in 1859. Although cholera had prevailed very severely there previously, in 1865 and 1866 there were only a few cases.[4] In Haarlem, in Holland, cholera prevailed in great intensity in 1849. In 1866 it returned, and again prevailed as severely in all parts of the town except one. The part entirely exempted in the second epidemic was inhabited by bleachers, who, between 1849 and 1866, had obtained a fresh source of pure water.[5] In the last epidemic in Spain (1885), Malaga, Seville, and Toledo drew water from pure sources, and had little cholera; on the other hand, Granada, Zaragoza, and Aranjuez derived water from open canals, and suffered severely.

In looking back, with this new reading of facts, it would seem that some older reported cases of sudden cessation of cholera can be explained, such as the case of Breslau in 1832, when the shutting up of a pump was followed by the very rapid decline of the disease. Doubtless, however, in other cases the causes of the cessation are different; heavy rain, by cleansing air and sewers, and by stopping the evolution of effluvia, will sometimes as suddenly arrest cholera. Most important evidence is given by Professor Förster of Breslau.[6] He shows that five towns of Silesia (of 5000 to 12,000 inhabitants) have been entirely free from cholera, which has never spread, even when introduced. The only common condition is a water supply from a

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[1] See Report on Hygiene. *Army Med. Dept. Report*, vol. xii. p. 241.
[2] *Die Kanalisation von Berlin*, 1868, p. 30.
[3] *Cholera in Oxford in* 1854, by H. W. Acland, M.D., p. 51.
[4] Hornemann in Virchow's *Archiv*, band 53, p. 156.
[5] Ballot, *British Med. Journal*, April 1869.
[6] *Die Verbreitung der Cholera durch die Brunnen*, Breslau, 1873.

distance which *cannot* be contaminated. In Glogau (13,000) half the water is from a distance and half from wells: those using the former remain free, those using the latter are attacked. In one case in Breslau, on a well becoming contaminated, eleven persons were immediately attacked.[1] Dr A. Fergus[2] has pointed out that in Glasgow, when the whole city was supplied from the river, cholera was universal in 1848; whilst in 1854 it was chiefly confined to the north side, which still drew water from the river, the south side with a pure water supply being practically free from it. In 1866 the whole city had the pure Loch Katrine supply, and although cases of cholera were imported, it got no hold on the city whatever.

So also other curious facts in the history of cholera become explicable. The prevalence of cholera in Russia, with an outdoor temperature below zero of Fahr., has always seemed an extraordinary circumstance, which it appeared only possible to explain by supposing that, in the houses, the foul air and the artificial temperature must have given the poison its necessary conditions of development. But Dr Routh has pointed out[3] that, in the poorer Russian houses, every thing is thrown out round the dwellings; then, owing to the cold and the expense of bringing drinking water from a distance, the inhabitants content themselves with taking the snow near their houses and melting it. It is thus easy to conceive that, if cholera evacuations are thus thrown out, they may be again taken into the body. This is all the more likely, as cholera stools have little smell or taste, and, when mixed even in large quantity with water, cannot be detected by the senses.

We may therefore conclude that the cholera evacuations, either at once or after undergoing some special fermentative or transformation change, pass into drinking water or float about in the atmosphere. In either case they are received into the mouth and swallowed, and produce their effects directly on the mucous membrane, or are absorbed into the blood. The relative frequency of each occurrence, the incubative period, and the severity of the disease produced, are points still uncertain.

C. Macnamara states[4] that the dangerous period is when the water into which cholera stools are passed is swarming with vibriones, and that when ciliated infusoria appear danger is over. He speaks strongly on this point, and from actual experience.

In addition to the production of cholera from drinking water containing the cholera stools, it has been supposed that the use of impure water of any kind *predisposes* to cholera, though it cannot absolutely produce the disease. The facts already quoted on the influence of the Lambeth water seem to support this view; but some German evidence in 1866 does not favour it,[5] although later evidence seems to do so.[6] If the water acts in this way, it may be by causing a constant tendency to diarrhœa, or by carrying into the alimentary canal organic matter which may be thrown into special chemical changes by a small quantity of cholera poison, which has been introduced with air or food and swallowed, or by lowering the resistance of the body, and rendering it more favourable as a nidus for the poison.

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[1] In India also similar results are found. Cullen cites the case of Hurda, rendered free from cholera by improved conditions of water supply. Payne reports that the new water supply of Calcutta has had the strongest effect in diminishing the mortality from cholera. See also the *Report on the Cholera in America in* 1873 for cases of water carriage.

[2] *British Medical Journal*, 1879, vol. ii. p. 336.

[3] *Fæcal Fermentation*, p. 24.

[4] *Asiatic Cholera*, p. 330.

[5] See Report on Hygiene, *Army Medical Dept. Report*, vol. vii. p. 325.

[6] Pistor of Oppeln, *Cholera Epidemic of* 1873-74; see 6th part of the *Report of the Cholera Commissioners of the German Empire.*

Yellow Fever.

As, like dysentery, enteric fever, and cholera, the alimentary mucous membrane is primarily affected in yellow fever, there is an *a priori* probability that the cause is swallowed also in this case, and that it may possibly enter with the drinking water. But no good evidence has been yet brought forward.

Boudin[1] quotes a case from Rochard in which a French frigate (in 1778) took in water at San Jago, where yellow fever prevailed. Some days afterwards yellow fever broke out with such violence that two-thirds of the crew were attacked. "And the proof that the only cause was the water," says Rochard, "was that the persons living with the captain had with them jars filled with water from Europe, and all escaped." Boudin very properly observes that this evidence is very defective; but yet we must remember how completely the propagation of marsh and enteric fevers, and of cholera by water, has been overlooked, and how exactly this sudden and extensive attack resembles the case of the "Argo."

The Barrack Commissioners have also directed attention to the fact of the great impurity of the water at Gibraltar at the time of the yellow fever epidemic; a difficulty which still remains to be dealt with in the event of the introduction of any epidemic disease.

The other Zymotic Diseases.

Of the other zymotic diseases the only ones likely to be propagated by means of water are *scarlet fever* and *diphtheria.* The evidence for such propagation was formerly very slight, but since attention has been drawn to the subject numerous cases have occurred which have been attributed to water-poisoning, working either directly through water drunk as such or by its being mixed with milk. There seems no *primâ facie* reason against such a channel of infection in the case of scarlet fever, particularly as epithelium scales are so often found in contaminated water. As regards diphtheria the question is a little more complicated, for the direct communication through the use of the same drinking vessel might simulate water carriage, as pointed out by Dr A. Downes.[2] Some important evidence has, however, been collected by Dr B. Browning[3] and others. It would also appear that ordinary throat ulcer (if this be really different from diphtheria) may be propagated in this way. It has been suggested that *erysipelas* is sometimes due to contaminated water, but of this, however, there is as yet no conclusive evidence.

4. DISEASES OF THE SKIN, AND SUBCUTANEOUS TISSUES.

A curious endemic of boils occurred in the vicinity of Frankfort in 1848. It was confined to a small number of persons, and presented favourable opportunities for investigation. An elaborate inquiry was made by Dr Clemens,[4] which certainly seems to indicate that the complaint was caused by drinking water containing hydrogen sulphide gas, which was set free in some large chemical works, and was washed down by the rains into the brooks from which drinking water was derived. The case is most elaborately and logically argued, but it certainly seems remarkable that

[1] *Traité de Geog. et de Stat. Med.*, 1858, t. i. p. 141.
[2] *Sanitary Record*, 1879-80, vol. xi. p. 51.
[3] *Sanitary Record*, vol. xi. p. 13.
[4] Henle's *Zeitschrift für Nat. Med.*, 1849, vol. viii. p. 215.

other instances of the same kind should not have been observed, especially as in some trades there is disengagement of large quantities of SH_2 into the atmosphere, and as the drinking of sulphuretted springs is so common.

The peculiar forms of boil or ulcer common in many cities in the East have been in some cases referred to the water. The Aleppo evil, the Damascus ulcer, and some other diseases of an analogous kind, which have the peculiarity of occurring only once in life, are possibly more connected with the true contagions; but the unhealthy boils or ulcers so common in India, especially in the north-west and along the frontier, are probably connected with bad water. The so-called Delhi boil has much decreased in frequency since the waters of the Jumna were used instead of the impure well-water,[1] but, on the other hand, Fleming's observations have thrown doubt on the fact of the water being to blame. The later observations of Drs D. Cunningham and T. Lewis have tended, on the other hand, to weaken those of Fleming, and to show that the water is probably to blame. With regard to the frontier ulcers in India, Dr Alcock, Medical Staff, has given some curious evidence, which seems to connect them with vegetable detritus and the evolution of hydrogen sulphide.

The elephantiasis of the Arabs (the so-called Barbadoes leg or Pachydermia) has been ascribed to organic impurities in water, which may be true, if the disease, as is now suggested, be due to a *Bacillus* which might be conveyed in water.

5. DISEASES OF THE BONES.

Water, impregnated with sulphurous acid, gives rise in cattle to a number of serious symptoms, among others to diseases of the bones. The sulphur dioxide evolved from the copper works at Swansea has caused numerous actions on account of the loss of herbage and cattle. Rossignol[2] states that water highly charged with calcium carbonate and sulphate was found to give rise to exostoses in horses; pure water being given, the bones ceased to be diseased.

6. CALCULI.

It has long been a popular opinion that drinking lime waters gives rise to calculi (calcium phosphate and oxalate). Several medical writers have held the same opinion, and have adduced individual instances of calculi (phosphatic?) being apparently caused by hard waters, and cured by the use of soft or distilled water. On a large scale, statistical evidence is apparently wanting. The excess of cases of calculi in Norwich and Norfolk generally is not, in Dr Richardson's opinion, attributable to the water.[3] Dr J. Murray, of Newcastle, has given some evidence[4] to show a connection between the lime waters and calculi, especially phosphatic, but it does not appear to be more convincing than that previously adduced.

At Canton stone is common, while at Amoy, Shanghai, Ningpo, and other places, it is not met with. The cause of the difference is not known, but it is not calcium carbonate in the water, as the Chinese always drink boiled water.[5]

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[1] See *Annual Report of San. Com. with the Government of India for* 1867, p. 178 (1868). Some excellent analyses of the Delhi waters are given by Dr Sheppard; *vide* D. Macnamara's *Second and Third Reports of the Analyses of Potable Waters in the Bengal Presidency*, Calcutta, 1868.

[2] *Traité d'Hygiène Militaire*, 1857, p. 357.

[3] *Med. History of England; Medical Times and Gazette*, 1864, p. 100.

[4] *British Medical Journal*, September 1872.

[5] Dr Wang, in *Chinese Customs Report for* 1870, p. 71.

Professor Gamgee, however, states that sheep are particularly affected by calculus in the limestone districts.

7. GOITRE.

The opinion that impure drinking water is the cause of goitre is as old as Hippocrates and Aristotle, and has been held by the majority of physicians. The opinion may be said actually to have been put to the test of the experiment, since both in France and Italy the drinking of certain waters has been resorted to, and apparently with success, for the purpose of producing goitre, and thereby gaining exemption from military conscription.[1] And this is supported by the evidence of Bally, Coindet, and by many of the French army surgeons, who have seen goitre produced even in a few days (8 or 10) by the use of certain waters.[2] While, conversely, Johnston saw goitre, which was common in a jail, disappear when a pure water was used.[3]

Apart from this, the evidence for the causation by water is extremely strong, many cases being recorded where in the same village, and under the same conditions of locality and social life, those who drank a particular water suffered, while those who did not do so escaped.[4] The latest author who has written on this subject, and who has accumulated an immense amount of evidence, M. Saint-Lager, expresses himself very confidently on the point.

The impurity in the water which causes goitre is not yet precisely known. It is certainly not owing to the want of iodine, as stated by Chatin, and there is little probability of its being caused by organic matters, by fluorine, or by silica. On the other hand, the coincidence of goitre with sedimentous water is very frequent. Since the elaborate geological inquiries of M. Grange[5] and the analyses of the waters of the Isère, magnesian salts in some form have often been considered to be the cause, to which many add lime salts also; and certainly the evidence that the water of goitrous places is derived from limestone and dolomitic rocks, or from serpentine in the granitic and metamorphic regions, is very strong. The investigations now include the Alps, Pyrenees, Dauphiné, some parts of Russia, Brazil, and districts in Oude in North-West India. A table compiled from Dr M'Clellan's work[6] is very striking:—

Goitre and Cretinism in Kumaon (Oude.)

Water derived from	Percentage of Population affected.	
	With Goitre.	With Cretinism.
Granite and gneiss, ...	0·2	0
Mica, slate, and hornblende, . .	0	0
Clay slate, ...	0·54	0
Green sandstone, ...	0	0
Limestone rocks, ...	33	3·0

[1] Among other evidence on this point, the work of M. Saint-Lager (*Sur les causes du Cretinisme et du Goitre endémique*, Paris, 1867) may be cited (p. 191 *et seq.*), as he appears to have carefully looked into the evidence. See also Baillarger (*Comptes Rendus de l'Acad.*, t. lv. p. 475), who states, though this has been denied by Rey, that horses and mules become affected from drinking the water of the Isére.

[2] *Encyclopædia of Practical Medicine*, vol. i. art. Bronchocele, p. 326.

[3] *Edin. Monthly Journal*, May 1855.

[4] Saint-Lager (*op. cit.*) cites several strong cases (p. 192 *et seq.*)

[5] *Ann. de Chimie et de Phys.*, vol. xxiv. p. 364.

[6] *Medical Topography of Bengal.* The facts on cretinism are also included, without desiring to express any opinion on the relation between goitre and cretinism.

There are, however, not wanting analyses of water of goitrous regions which show that magnesia may be absent (in Rheims, according to Maumené; in Auvergne, aeeording to Bertrand; in Lombardy, according to Demortain; and Saint-Lager enumerates other cases), while it has been also denied that there need be any excess of lime. M. Saint-Lager, basing his opinion partly on these negative instances, partly on his own experiments with the soap-test, which show no relation between hardness of water and goitre, and partly on the negative results of experiments on animals with calcium sulphate and magnesian salts, denies altogether the connection between goitre and calcium and magnesium sulphates and carbonates. He states also that M. Grange has now himself given up the belief of magnesia being the essential agent of goitre,[1] and argues that the eonstituent of the water which is the actual cause is either iron pyrites (ferrum sulphide), or more infrequently copper or some other metallic sulphide. And he explains M'Clellan's results by the supposition, based on an expression of that writer, that in the limestone districts of Kumaon the water had traversed the metalliferous strata of the rocks. Saint-Lager does not support his opinion by actual chemical analyses, but he brings forward geological evidence on a large scale to prove that the endemic appearance of goitre coincides with the metalliferous districts. He has also made experiments on animals with iron salts whieh do not appear conclusive, although he believes he produced in some cases an effect on the thyroid. His hypothesis seems to fail from his want of chemical analyses. He has made out a case for inquiry rather than for conclusion.

In some observations made by Dr Ferguson on the goitrous part of the Baree Doab district [2] (a boulder-gravel subsoil), the water is said to be largely charged with lime. In the jail at Durham, Johnston [3] states that when the water contained 110 parts per 100,000 (chiefly of lime and magnesium salts) all the prisoners had swellings of the neck ; these disappeared when a purer water, containing 26 parts per 100,000, was obtained.[4]

Goitre may be rapidly produced. Bally noticed that eertain waters in Switzerland would cause it even in eight or ten days, and cases almost as rapid have occurred in other places.[5]

Dr J. B. Wilson (late A.M.D.) carried out some inquiries at Bhagsoo, Dhurmsala, where goitre prevails extensively. He analysed specimens of the drinking water within a radius of ten miles, and found them exceptionally pure, only three showing traces of lime, and none giving any evidence of magnesia or iron.[6]

It seems, therefore, that the question is still undecided, and it is much to be desired that more extended inquiry should be made, with careful analyses, such as have been made by Dr Wilson,—as well as reeords of local and other conditions, which probably eontribute more or less to the produetion of the disease.

8. ENTOZOA OR OTHER ANIMALS.

Whereas the *Tænia solium* and the *Tænia mediocanellata*, and many entozoa, find their way into the body with the food,[7] the two forms of the

[1] *Sur les causes du Cretin. et du Goitre*, p. 237.
[2] *Sanitary Administration of the Punjab for* 1871, Appendix 4, p. 33.
[3] *Edin. Monthly Journal*, May 1855.
[4] In Nottingham the people attribute goitre to hardness of water. Generally it appears only with magnesium limestone.
[5] Many instances are recorded in the Freneh military medieal journal, *Recueil de Mém. de Méd. Mil.*, of the acute goitre produced in a few days.
[6] *Indian Annals of Medical Science;* also Aitken's *Science and Practice of Medicine*, 7th edit., vol. ii. p. 1009.
[7] Dr Oliver's observations in India show that cattle may get *tænia* ova from the water ; so that men may do the same. (See Aitken's *Med.*, 7th ed., vol. i. p. 207).

Bothriocephalus latus (*T. lata*) may pass in with the drinking water.[1] Both embryo and eggs (but principally, or perhaps entirely, the former) exist in the river water. The ciliated embryo moves for several days very actively in water; it may after a time lose its ciliary covering, and then, not being able to move further, perishes; or it may find its way into the body of some animal, and there develop into the *Bothriocephalus latus.*

It is most common in the interior of Russia, Sweden, in part of Poland, and in Switzerland.

Distoma hepaticum (*Fasciola hepatica*).—The eggs are developed in water, and the embryos swim about and live, so that introduction in this way for sheep is probable, and for men is possible.

The *Ascaris lumbricoides* (Round-worm) appears also sometimes to enter the body by the drinking water. At Moulmein, in Burmah, during the wet season, and especially at the commencement, both natives and Europeans, both sexes and all ages, were, in former years, so affected by lumbrici that it was almost an epidemic.[2] The only circumstance common to all classes was that the drinking water, drawn chiefly from shallow wells, was greatly contaminated by the substances washed in by the floods of the excessive monsoon which prevails there. Dr Paterson[3] has also noticed similar facts in England.

Leuckart[4] has no doubt of the passage of the *ascarides*' eggs into drinking water; and, indeed, they have been actually seen in the water by Mosler.[5] But it seems yet doubtful (as all experiments have failed in producing from the drinking water the worms in animals) whether the eggs alone will suffice, and it seems possible that they must pass through some other host before developing in the human intestine. This was also the opinion of Cobbold. Mosler attributed in his case much influence to the large amount of vegetable food taken by the persons affected.

The *Dochmius duodenalis* (*Strongylus duodenalis, Anchylostomum seu Sclerostoma duodenale*) would appear from Leuckart's statement[6] to be introduced by impure water.[7]

Oxyuris vermicularis, very common in children, but occasionally also found in adults, is probably sometimes taken through water.[8]

Filaria Dracunculus (Guinea-worm).—The introduction by water of *Filaria* has long been a favourite opinion. It has been a matter of debate whether it is taken into the stomach as drink, and thence finds its way (like *Trichina*, to the muscles) into the subcutaneous cellular tissue, or whether it penetrates the skin during bathing or wading in streams. The latter opinion seems to be the more probable in the majority of cases.[9]

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[1] See especially a paper by Dr Knoch in the *Peterburger Med. Zeitsch. for* 1861. An abstract is given in the *Lancet*, Jan. 25, 1862; and the paper in full is printed in Virchow's *Archiv*, band xxiv. 453. Cobbold, however, doubted the direct entrance in this way, and thought it more probable that fish form the *host* for the ova, which after development in the fish, may find their way into the bodies of men who eat the fish.

[2] The native treatment is the powder of a *fungus* (Wah-mo), derived from the female bamboo. It is most useful. See paper by Dr Parkes in the *London Journal of Medicine*, 1849.

[3] Aitken's *Practice of Medicine*, 7th ed., i. p. 157.

[4] *Die Menschlichen Parasiten,* band ii. p. 220.

[5] Virchow's *Archiv*, band xviii. p. 249.

[6] *Ibid.*, band ii. p. 465.

[7] The importance of the discovery of Griesinger (*Archiv für Phys. Heilk.*, 1854, p. 555), that the so-called widely spread Egyptian chlorosis is caused by *Dochmius duodenalis*, has hardly been sufficiently appreciated. Not only anæmia and liver diseases, but symptoms referred to dysentery and hæmorrhoids, are often also produced. And as similar facts have now been observed in Brazil, Arabia, and Madagascar, it seems impossible but that in India the formidable affections caused by *Dochmius* should be common.

[8] Aitken, vol. i. p. 183.

[9] See Sir W. Aitken's long and excellent chapter on this disease, in his *Practice of Medicine*, 7th ed., vol. i. p. 169 *et seq.*, for a discussion on the water and earth question.

Boiling the water before drinking appears to have a preservative effect.[1]

Filaria sanguinis hominis (Lewis) appears to find its way into the blood of man through water in a curious way. "Dr. Manson has found that the mosquito is an active agent in the propagation of *Filaria*. The embryos are taken into the mosquito's stomach with the blood of persons infected by the hæmatozoon, the further development of which shortly begins in the stomach of the mosquito. Thence they are transferred to the water, whence it is assumed that it again finds entrance into the body of man."[2]

Bilharzia hœmatobia.—From the observations of Griesinger, John Harley,[3] and Cobbold, there seems no doubt that the embryos of this entozoon live in water, and the animal may be thus introduced probably by the medium of some other animal. Dr Batho doubts, however, this introduction by water, since the entozoon occurred in persons using rain-water and pure mountain stream water.[4]

Leeches.—Reference has already been made to the swallowing of small leeches, which fix on the pharynx, and in the posterior nares. Cleghorn[5] noticed that coughs, nausea, and spitting of blood were thus caused. In a march of the French near Oran, in Algiers, more than 400 men were at one time in hospital from this cause. In some cases the repeated bleedings from the larynx have simulated hæmoptysis and phthisis, and have produced anæmia. A leech, once fixed, seldom falls off spontaneously. In India no accidents of this kind are on record, yet we must assume that they occasionally occur.

9. LEAD, MERCURY, ARSENIC, COPPER, AND ZINC POISONING.

It is only necessary to mention the fact of metals passing into the drinking water, either by trade refuse being poured into streams, or by the water dissolving the metal as it flows through pipes or over metallic surfaces.

In 1864 a factory at Basle discharged water containing arsenic into a pond, from which the ground and adjacent wells were contaminated, and severe illness in the persons who drank the well-water was produced.[6]

General Conclusions.

1. An endemic of diarrhœa, *in a community*, is almost always owing either to impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the two last causes: and if it extends over many families, almost certainly to water. But as the cause of impurity may be transient, it is not easy to find experimental proof.

2. Diarrhœa or dysentery, constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause.

3. A very sudden and localised outbreak of either enteric fever or cholera is almost certainly owing to introduction of the poison by water.

4. The same fact holds good in cases of malarious fever, and, especially if the cases are very grave, a possible introduction by water should be carefully inquired into.

5. The introduction of the ova of certain entozoa by means of water is proved in some cases—is probable in others.

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1 Greenhow, in *Indian Annals*, 1856, p. 557.
2 Aitken, *op. cit.*, i. 185.
3 *Med. Chir. Trans.*, vol. xlvii. p. 65, and vol. lii. p. 379.
4 *Army Med. Rep.*, vol. xii. p. 504.
5 *Diseases of Minorca*, 1768, p. 38.
6 Roth and Lex, *Milit. Gesundsheitpfl.*, p. 41.

6. Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on the public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water supply is given; and, apart from this actual evidence, we are entitled to conclude, from other considerations, that abundant and good water is a primary sanitary necessity.

SECTION IV.

PURIFICATION OF WATER.

Without Filtration.

1. *Distillation.*—This is undoubtedly the best plan, for if properly carried out all danger is got rid of. It has been suggested that foul gases may be brought over from dirty water, and that even *bacteria* or their spores may be transmitted; this is more than doubtful. An outbreak of diarrhœa among H.M. ships in the harbour of Valetta (Malta) was attributed to impurities in the water distilled from the not over-clean water of the Grand Harbour. The distilled water was also complained of as "going bad" very quickly in the Soudan campaign; but there the dirty water of the harbour of Suakim was used, and in such a case there is great danger of the original water getting in if the apparatus leaks or is in any way out of order. All distilled water should be tested with a few drops of dilute nitric acid and silver nitrate; if no haze appears, then the water may be considered safe: all other waters will give evidence of the presence of chlorine, by the formation of a precipitate, turbidity, or haze according to the amount; and so will distilled water (so-called), if it has been contaminated during the process of distillation, or by being received in vessels not perfectly clean.

2. *Boiling.*—This plan is next best to distillation: it gets rid of calcium carbonate, iron in part, and hydrogen sulphide, and lessens, it is said, organic matter. Tyndall's experiments have shown that there are stages in the life of *bacteria* during which they can resist almost any moist heat. But as they soften before propagation a solution can be successfully sterilised by repeated boilings, so as to attack the several crops of *bacteria* in their vulnerable condition. Most *fungus* spores are killed by boiling. On the whole we may take it that water, even only once boiled, is in all likelihood safe, and, if repeatedly boiled at intervals, quite safe.

3. *Exposure to Air in divided Currents.*—This was a plan proposed by Lind for the water of the African west coast more than one hundred years ago, and frequently revived since. The water is simply poured through a sieve, or a tin or wooden plate, pierced with many small holes, so as to cause it to fall in finely-divided streams, or a hand-pump is inserted in a cask of water, and the water is pumped up and made to fall through perforated sheets of tin. It soon removes hydrogen sulphide, offensive organic vapours, and, it is said, dissolved organic matter. The same plan has been used in Russia on a large scale, the water being allowed to fall down a series of steps passing through wire gauze as it does so. In Paris, also, it has been employed on the small scale.

4. *Aluminous Salts.*—Alum has been used for centuries in India and China to purify water from suspended matters. It does this very effectually if there be calcium carbonate in the water; calcium sulphate is formed, and

this and a bulky aluminium hydrate entangle the floating particles and sink to the bottom. The quantity of crystallised alum to be used should be about 6 grains per gallon ($8\frac{1}{2}$ per 100,000).[1]

If a sedimentous water is extremely soft, a little calcium chloride and sodium carbonate should be put in before the alum is added.

5. *Addition of Lime Water* (Clark's patent).—By combining with carbonic acid, it causes almost all the calcium carbonate previously and newly formed to be thrown down. It also throws down suspended and a certain proportion of dissolved organic matters; and also, it is said, iron. It appears to act favourably in arresting organisms. It does not touch calcium and magnesium sulphate and chloride.[2]

6. *Sodium Carbonate*, with boiling, throws down lime, and possibly a little lead, if present.

7. *Addition of Potassium or Sodium Permanganate* (Condy's red fluid).—Pure Condy's fluid readily removes the smell of hydrogen sulphide and the peculiar offensive odour of impure water which has been kept in casks or tanks. If it forms a precipitate of manganic oxide, it also carries down suspended matters; but the formation of this precipitate is very uncertain. The action on the dissolved organic matters will, of course, vary with the nature of the substance; some of the organic matters, both animal and vegetable, will be oxidised; but in the cold it will not act upon the whole of these substances, and some organic matters are not touched.

One objection to the use of the permanganate is that it often communicates a yellow tint to the water, arising from suspended finely divided peroxide of manganese. This is probably of no moment as far as health is concerned, but it is unpleasant. Sometimes the addition of a little alum will carry down this suspended matter; boiling may be used, but often has no effect. Sometimes nothing removes it but filtration.

The indications for the use of permanganate are these. In the case of any foul-smelling or suspected water, add good Condy's fluid, teaspoonful by teaspoonful, to 3 or 4 gallons of the water, stirring constantly. When the least permanent pink tint is perceptible, stop for five minutes; if the tint is gone, add 36 drops, and then, if necessary, 30 more, and then allow to stand for six hours; then add for each gallon 6 grains of a solution of crystallised alum, and if the water is very soft, a little calcium chloride and sodium carbonate, and allow to stand for twelve or eighteen hours.

There are many cases in which this plan may be useful; and as the permanganate certainly removes smells and oxidises in the cold to some extent, it is a very good introduction to the alum process, and does work which alum alone will not do. But it cannot be considered a complete purifier of water from all organic matters.

8. *Perchloride of Iron.*—It has been found that the water of the Maas in Holland, which is turbid from clay and finely suspended organic matters, and gives rise in consequence to diarrhœa, is completely purified by perchloride of iron in the proportion of about $2\frac{1}{2}$ grains of the solid perchloride to 1 gallon of water, $3\frac{1}{2}$ to the 100,000.[3] It is a powerful oxidising agent.

9. *Use of the Strychnos potatorum.*—In India the fruit of the *Strychnos potatorum* is used, especially by the better class of Hindoos, to purify

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[1] The headquarter wing of the 92nd Highlanders, going up the Indus in 1868, suffered from diarrhœa from the use of the water; the left wing used alum and had no diarrhœa. The right wing then used it, and the diarrhœa disappeared.—*Indian Medical Gaz.*, Aug. 1869, p. 158.

[2] This plan has been carried out with great success on a large scale in the form known as the Porter-Clark process, and also in a modified form by Messrs Atkins and others.

[3] *Chemical News*, May 1869, p. 239.

water. It is beaten into a paste, and rubbed on the inside of the water jar or cask. Its usefulness is doubtful.

10. *Immersion of Iron Wire and Magnetic Oxide of Iron* (Medlock).—This plan is said to decompose organic matter. Charcoal and ferric oxide are sometimes mixed.

11. *Immersion or boiling of certain Vegetables*, especially those containing tannin, such as tea,[1] kino, the Laurier rose (*Nerium Oleander*, which is also rubbed on the inside of casks in Barbary), bitter almonds (in Egypt).

12. *Charring the inside of Casks.*—This is an effectual plan, and Berthollet considered it more effectual than the immersion of pieces of charcoal; the charring can be renewed from time to time.

13. P. F. Frankland's [2] experiments seem to show that agitation with small fragments of certain substances effectually purifies water from organisms. *Coke* has a powerful influence, and so has *spongy iron.* Later Anderson [3] has shown that *scrap iron* is equally efficacious, so much so that it is now used at Antwerp in the extension works instead of spongy iron.

To put these facts in another form:—

Organic matter is got rid of most readily by distillation, boiling, exposure to air, agitation, especially with small fragments of charcoal, coke, or spongy iron, alum, potassium permanganate, astringents.

Carbonate of lime, by boiling and addition of caustic lime. Various powders are sold for softening water; they consist mainly of lime with a little soda; they remove temporary hardness, but very slightly affect the permanent.

Iron, by boiling and lime water, and in part by charcoal.[4]

Calcium and magnesium sulphate and chloride cannot be got rid of, except very partially. Mr Maxwell-Lyte has suggested the use of sodic aluminate for this purpose, but experiments at Netley with it were not very satisfactory.

The use of barium salts to precipitate the sulphuric acid, and the stream of CO_2 to precipitate the lime, has also been proposed, but the process would be expensive, and not free from danger.

It should be remembered that some water plants have a purifying effect, apparently from the large quantity of oxygen they give out; and this takes place sometimes though the water itself is green.

With Filtration.

Sand and Gravel.—On a large scale, water is received into settling reservoirs, where the most bulky substances subside, and is then filtered through gravel and sand, either by descent or ascent, or both.[5]

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[1] In the north of China, and especially during winter, the water of the Peiho becomes very impure, and contains, not only suspended matters, but dissolved animal matter in large quantity, which gives the waters a disagreeable offensive smell. The Chinese never drink it except as tea, which is cooled with a lump of ice if it is desired to drink it cold. In this way they secure themselves from all bad effects of this water (Friedel, *Das Klima Ost-Asiens*, p. 60). The Europeans use alum and charcoal; but these do not always entirely remove the taste. The Tartars also use their "brick tea" to purify the water of the steppes, which would otherwise be undrinkable.

[2] *Proc. Roy. Soc.*, *loc. cit.*

[3] *Proc. Inst. C.E.*, vol. lxxxv.

[4] Chevalier, *Traité des Désinfect.*, p. 147. In the Ashanti campaign, under the directions of Surgeon-Major V. Gouldsbury, C.M.G., the water was purified in the following way, in the absence of proper filters:—Alum was added to precipitate suspended matter; the water was passed through a rough filter, consisting of (1) sponge, (2) sand, (3) charcoal in pieces; it was then boiled, and a few drops of solution of potassium permanganate added. Water, even taken from a hole in a marsh, was innocuous after this treatment.

[5] A good account of the engineering plans and filtration of the London water companies will be found in a work called *The Water Works of London*, by Messrs Colburn & Shaw, 1867.

The London water companies usually employ a depth of 3 to 5 feet; in the latter case, the upper stratum of 18 inches or 2 feet is composed of sand, the lower 3 feet are made up of gravel, gradually increasing in coarseness, from pieces the size of a small pea and bean to that of a middle-sized potato. A stratum of oyster shells, about $1\frac{1}{2}$ inch in thickness, has been used by some companies instead of a layer of gravel; but this plan is not general. If the filter is 3 feet in thickness, the upper 15 inches are sand, and the lower 21 inches are gravel.

The pressure of water in these filters is not great; the depth of the water is never above 2 feet, and some companies have only 1 foot. From 70 to 75 gallons is the usual quantity which should pass through in twenty-four hours for each square foot; but some companies filter more quickly, viz., at the rate of a gallon per twenty-four hours for each square inch, or 144 gallons per square foot.

The sand should not be too fine; the sharp angular particles are the best. The action seems chiefly, though not altogether, mechanical; the suspended impurities, both mineral and organic, rub upon and adhere to the angles and plane surfaces of the sand, which are gradually encrusted, and after a certain time the sand has to be cleaned. The effect on suspended matters, both organic and mineral, is certainly satisfactory. On dissolved organic matter it is less so. Mr Witt's experiments show only a removal of about 5 per cent.

Some experiments were made at Netley on a sand filter of 1 square foot surface, and made in imitation of a London water company's filter, viz., 15 inches of fine well-washed white sand, and $20\frac{1}{2}$ inches of gravel, gradually increasing in coarseness. The first eight gallons were thrown away, so as to avoid the fallacy of including the distilled water with which the sand had been washed.

This sand filter had some effect in lessening the dissolved constituents, both mineral and organic, but the effect was limited; it stopped organic matter after it had ceased to arrest lime. After a longer time it became useless, and required washing.

On dissolved mineral matters sand exerts at first, and when in thick layers, a good deal of action; much sodium chloride can be removed; and Professor Clark has stated that even lead can be got rid of by filtering through a thick stratum. Very finely divided clay seems to pass through more readily than any other suspended matters.[1]

The experiments of Dr Percy Frankland,[2] by the biological test of cultivation, show that the power of some sand is at first considerable, but

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[1] A peculiar difficulty, never experienced in England, was discovered in the filtering, through sand, of the Hooghly water at Calcutta. During the rainy season the fine mud brought down penetrates very deeply into the filters, and rapidly chokes them; in the dry seasons this does not happen: the suspended matters are arrested, as in England, near the upper surface of the sand. Mr D. Waldie (*Journal of the Asiatic Society of Bengal for* 1873, part II, p. 210) explains this by showing that in the rainy season the water contains much less saline matter than in the dry season; it is this saline matter which seems to act on and so cause coherence of the particles of mud, so that they become larger and coarser, and are more easily arrested. In order to remedy this, Mr Waldie proposes the addition of substances to the water, during the rains, which may cause this coalescence; he has tried a great number of experiments and different substances; on the whole crystallised alum and perchloride of iron are the best; 55·4 ℔ of crystallised alum, or 19·15 ℔ of perchloride of iron. were found to be necessary for the clarification of one million gallons of muddy Hooghly water during the rainy season.

Higgin found pounded cinders in sand removed the yellowish opalescence of the River Plate water.

[2] See *Proc. of Roy. Soc.*, vol. xxxviii. p. 382; also *Proc. Inst. Civil Engineers*, vol. lxxxv.; also *Transactions of the Sanitary Institute of Great Britain*, vol. viii., York Congress.

that it ceases after a time. Ferruginous green sand arrested all organisms at first; after thirteen days it arrested 88 per cent., filtration being carried on at the rate of 0·73 gallons per square foot per hour; after one month there was a reduction of organisms to the extent of 39 per cent., at a filtering rate of 1·14 gallon per square foot per hour. The efficiency of this sand is therefore greater than might have been supposed.

The fine white sand chosen carefully, well washed, and, if possible, heated to redness before use, has hitherto been thought the best, but P. Frankland's experiments show that its power of arresting organisms is only moderate, much inferior to that of the ferruginous green sand.

Instead of sand and gravel, trap rock has been used. Even pulverised bricks have some effect for a time (P. Frankland).

Sponge.—Sponge has a considerable effect in mechanically arresting suspended particles, but very little on dissolved matters. It soon clogs, and ought not to be used.

Animal Charcoal.—Pure animal charcoal (deprived, as far as possible, of calcium phosphate and carbonate by washing or by hydrochloric acid) used to be considered one of the best filtering materials. The particles of charcoal should be well pressed together, and the passage of the water should not be too quick. Contact with the water for about four minutes appears sufficient. There is a large (and, if the layer of charcoal be deep enough, complete) removal of suspended matters, both mineral and organic; water even deeply tinged comes through a good charcoal filter very clear and bright. So also dissolved organic and mineral matters are removed by charcoal in the first instance. All evidence agrees in respect of that point. But then its power is limited, and after a time it ceases to be efficient.

In experiments made with animal charcoal at Netley (by Drs F. de Chaumont and J. L. Notter) it was found that it had a very rapid and powerful effect upon dead or decomposing organic matter, but that it allowed fresh organic matter, such as fresh egg albumin, to pass through to a large extent unchanged.[1] This suggests serious considerations with reference to the effect upon disease poisons. It was also found (as in Mr Byrne's experiments) that after a time the filtering action not only ceased, but that the charcoal began to give back some of the organic matter it had removed. The same result takes place if the water be left too long in contact with the charcoal. Water filtered through charcoal, if it be kept for any length of time, shows some evidence of low forms of organic life,—in some instances a copious deposit forming. This may be due either to spores or germs passing through unchanged,[2] or to the phosphates yielded by the charcoal affording a favourable nutrient for germs absorbed from the atmosphere. These conclusions have been fully confirmed by Dr P. Frankland's[3] cultivation experiments, in which he found that during the first twelve days the animal charcoal effectually kept out all germs; but after a month the filtered water was more highly impregnated (nearly five times) than the original water. For these reasons it seems unadvisable to use charcoal for filtration on a large scale, independent of the consideration of expense. The plan of placing charcoal filters in water cisterns, now often practised, ought also to be given up. The conclusions to be arrived at with regard to charcoal as a filtering medium are these:—(1) It acts both chemically and mechanically, and is at first both rapid and efficient.

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[1] See *Sanitary Record*, Oct. 1876, p. 288, and *A.M.D. Reports*, vol. xix. p. 170.

[2] This appears the more probable. Minute diatoms were found in water which had been kept for some months after being passed through Crease's large filter tanks at Parkhurst.

[3] *Proc. Roy. Soc.*, *loc. cit.*

(2) With a good bulk of material, water may be passed through nearly as rapidly as it can flow, and be well purified. (3) Water must not be left in contact with the charcoal longer than is necessary for filtration, as it is apt to take up organic matter again. (4) Water filtered through charcoal must not be stored for any time, but must be used immediately, as if kept it is apt to become charged with minute living organisms. (5) Since fresh organic matter may pass through it unchanged, animal charcoal cannot be confidently depended upon to purify water from disease poison. (6) The power of charcoal is limited; with a moderately good water it remains efficient for some time, but with an impure water it soon becomes inactive. In all cases it ought to be cleaned or renewed at least every three months, and with impure waters much oftener, say, every week or every fortnight.

Vegetable Charcoal—Peat Charcoal—Seaweed Charcoal.—The first is much less efficacious chemically than animal charcoal,—even useless, according to E. Frankland. But P. Frankland's biological experiments show it to be much more efficacious and lasting in its powers than animal charcoal. The others are rather more effectual chemically, but their biological power has not yet been tested.

Coke shows remarkable powers of keeping back organisms, at least for a time; indeed, it is equal to animal charcoal at first, and retains its power longer.

Spongy Iron.—This substance, obtained by roasting hæmatite iron ore, is porous metallic iron, probably mixed with magnetic oxide, and not unlike animal charcoal in appearance. It occupies a space of about twenty cubic feet to the ton. Its action on water is both mechanical and chemical, for it arrests suspended matter and also oxidises organic matter in solution. It acts upon water itself, decomposing it and setting free hydrogen,—the oxygen being afterwards given up to organic matter that may come in contact with it. Its oxidising power is very great, although perhaps a little slow. Experiments at Netley[1] showed that it could be depended upon to remove the greater part of the dissolved organic matter, and with prolonged exposure the whole of it in many instances. It has not much effect on mineral matter, but removes lead. It yields a little iron to the water, which, however, can be removed by further filtration through prepared sand,—that is, sand or fine gravel with pyrolusite. Beyond this nothing is yielded to the water, which comes out quite clear and pure, and may be stored for a long time without undergoing any change or showing signs of the production of living organisms,—or in any way favouring putrefaction.[2] Water left in contact with it does not deteriorate. It retains its filtering power a long time,—very much longer than animal charcoal. Those qualities are fully confirmed by the biological experiments of P. Frankland. Such properties render it suitable for use on a large scale, and it has been so used in several places, as, for example, in the Water Works of Antwerp. On the whole, it must be looked upon as one of the most powerful and lasting filtering media we have.

Carferal.—This substance is no longer in the market; a substance of somewhat similar character, called *Carbalite*, has been used instead in Crease's filters.

Domestic Filters.—On a small scale, a number of substances have been used, such as animal and vegetable charcoal, in granules or powder, or

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[1] *A.M.D. Reports*, vol. xx. p. 205 *et seq.*

[2] See M. Gustav Bischof, "On Putrescent Organic Matter in Potable Water," *Proc. Roy. Soc.*, No. 80, 1877; also "Sanitary Notes on Potable Water," *Sanitary Record*, vol. x. p. 237.

made into blocks, or fine silica impregnated with charcoal (silicated carbon filters), hæmatite and magnetic iron ores, the so-called magnetic carbide, spongy iron, manganic oxide, flannel, wool, sponges, porous sandstones (natural and artificial), &c.

The "Filtre Rapido" of Maignen is an ingenious arrangement, by which a large straining surface is presented to the water by the spreading of asbestos cloth over a frame, or over a perforated cone of porcelain. Any filtering medium in powder or granules may be mixed with the water and settles on the cloth; this, of course, can be renewed as required. These are now used in the army, both in garrison and in the field.

The "Filtre Chanoit" is much used in France. The straining material is ground slag ("Scorie de fonte"), and the filter requires to be used under pressure (5 centimetres); by this means a cushion of air is compressed, and acts as a purifier.

The Chamberland filter, used by Pasteur, consists of a cylinder of porcelain through which the water is forced. According to P. Frankland, it has little or no effect on the chemical constituents in solution, but it effectually strains off all organisms and their spores.

The filters in the market in this country are very numerous, but the most important are the following:—

1. Those containing animal charcoal, in granules or powder.
2. Animal charcoal compressed into blocks by admixture with silica and other substances.
3. Spongy iron filters.
4. Magnetic iron filters.
5. Those containing other substances of a nature chiefly mineral.

The essentials of a good filter are the following:—

1. That every part of the filter shall be easily got at, for the purposes of cleaning, or of renewing the medium.
2. That the medium have a sufficient purifying power both as to chemical action on organic matter in solution and arrest of organisms or their spores in suspension, and be present in sufficient quantity.
3. That the medium yield nothing to the water that may favour the growth of low forms of life.
4. That the purifying power be reasonably lasting.
5. That there shall be nothing in the construction of the filter itself that shall be capable of undergoing putrefaction, or of yielding metallic or other impurities to the water.
6. That the filtering material shall not be liable to clog, and that the delivery of the water shall be reasonably rapid.

The *first* of these conditions obviously sets aside all filters of the older, and what used to be the usual, pattern, where only a small layer of filtering material was present, which was cemented up, so as not to be reached without breaking open the apparatus.

The *second* condition is fulfilled, so far as filtering power is concerned, by a number of media, chiefly spongy iron, magnetic oxide, or carbide of iron, and charcoal for a short time. Coke, sand, and some other substances arrest organisms for some time, but do not affect the organic constituents chemically. With regard to bulk of material, this is fairly well attended to in the filters where loose material is used; but where solid blocks are employed the size is often quite incommensurate with the work they are called upon to do.

The *third* condition is complied with by spongy iron, magnetic oxide or carbide, and some other materials; but (as before mentioned), not by animal charcoal in the loose condition. As solid blocks, it seems to yield less to water than in the granular condition.

The *fourth* condition depends a good deal upon the relative degree of impurity of the water. The spongy iron and the magnetic oxide or carbide, on the whole, last the longest.

The *fifth* condition demands that nothing organic shall be used in the construction of the filter, or in the packing of the interior.[1] Iron or other metal must be protected from the action of the water.[2]

The *sixth* condition is generally fulfilled when the material is loose, and when the water is not too full of suspended matter. Sometimes sponge is used to arrest suspended matter, but it is so apt to get foul that its use had better be avoided. The block filters are very apt to clog, a slimy substance forming on their surface. This is partly obviated now by the use of asbestos strainers (as in the silicated carbon filter). Spongy iron is apt to cake unless kept constantly covered with water, but this is arranged for in the new forms of filter. As regards rapidity of delivery, the animal charcoal has the advantage over spongy iron and block filters, in the following ratio:—

1. Animal charcoal,	water runs through fairly well purified in $2\frac{1}{2}$ to 4 minutes.
2. Silicated carbon,	average exposure, 15 minutes.
3. Spongy iron,[3]	,, ,, 22 ,,

It is obvious that, for reasons of convenience, one filter may be preferable to the others according to circumstances. If the water is required immediately in considerable quantity, and is to be consumed at once, animal charcoal would be used, but would require frequent renewal, as is the case in the Filtre Rapide. In the other cases, where the delivery is slower, the size or the number of the filters would have to be arranged accordingly.

Cleansing of Filters.—All filters when first taken into use require to be washed by passing from 10 to 20 gallons of fairly good water through them, according to the size of the filter, as the filtering medium generally yields something to water in the beginning. It is also necessary to ensure the removal of dust, &c., that may be in the apparatus. But after a certain time of use all filtering media not only cease to be efficient, but even in some instances give up impurity to the water passed through them; so much is this the fact that cases of illness have been traced to this source, and some persons have thought the dangers of filtration were greater than those of unfiltered water. There is no doubt that the practice of depending for years upon the efficiency of a filter, which has never been cleaned or had its material renewed, is fraught with danger; and there is still danger to be apprehended from many of the so-called "self-cleaning" filters, which, in the words of advertisements, "require no attention." There is a limit to the power of all filtering materials, and no implicit confidence can be placed in any of the methods vaunted as "self-cleaning." It is not possible to state positively the length of time any filtering material will remain efficient, so much depending upon the con-

[1] Cotton has sometimes been used, and gone rapidly to decay.

[2] Water has been found strongly charged with zinc, from the use of so-called galvanised iron in filters.

[3] Water can be drawn off much more rapidly from this filter, if required, but this is not recommended by the inventor.

dition of the water and the quantity passed through. *Animal charcoal* in granules or powder ought to be cleaned or renewed at least every three months, and much oftener if used with dirty waters. The best plan of cleaning is to heat it to redness under cover, and then wash it with distilled water or the cleanest that can be procured. Failing this, boiling it, with or without permanganate of potassium solution or dilute Condy's fluid and a little mineral acid, is the safest plan. After this it may be exposed to the air and sun, thoroughly washed, and then used again. The permanganate solution (or Condy's fluid) should be passed through it until it comes out a distinct pink colour.

Spongy iron retains its efficiency for a long time, and, as in the filters made with it the flow of water is expressly limited with reference to the bulk of material, the difference is solely in relation to the greater or less impurity of the water acted upon. Its efficiency may generally be depended upon for a year, and, unless the water be very impure, even for a considerably longer time. The experiments (by cultivation) of P. Frankland would seem to indicate a much earlier failure of efficiency, and it would be well to have the water tested both chemically and biologically at intervals to be assured of the continued efficiency of the medium. When the limit of efficiency is reached, the only safe plan is to renew the charge of material, and it is generally advisable to provide for this renewal once a year, or oftener if examination of the water indicates the necessity of it; should circumstances arise, however, to prevent this renewal, the best plan for cleaning is to subject all the material to the action of fire, up to a low red heat, then to wash the whole well, and return it into the filter. The cleansing with permanganate and acid *must not* be attempted.

Filters, where the material is cemented up and cannot be removed, ought to be abandoned altogether.

Strainers of sponge, or any material which cannot stand the action of fire, ought also to be given up. Asbestos forms an excellent strainer, and can be heated to redness, so as to destroy all organic matter, as often as required.

Block Filters are generally undesirable forms; but, if used, they may be cleansed by carefully brushing the surface, pumping air in the reverse way, and treating with permanganate as above described. They are of various sizes, from small pocket filters to large-sized domestic filters delivering 30 to 50 gallons a-day. The pocket filters are useful as strainers, but their small size must make the duration of their oxidising power very short. They ought to be frequently brushed and washed in clean water, with permanganate if possible.

Cistern and Pipe Filters.—Filters are sometimes placed in cisterns, being constantly immersed in the water to be filtered. This is an objectionable plan, and ought to be abandoned. Pipe filters are those which are placed in the course of a supply pipe, and tap-filters those which are fitted on to a delivery tap. The objection to most of those filters is that they are generally much too small for the work expected from them, as they are usually represented by a small cylinder of block carbon or a few ounces of animal charcoal. For proper filtration the only way is to have a full-sized filter attached to the supply pipe, with a ball-cock or similar apparatus for filling it.[1] The object is of course two-fold,—first, to ensure that all the water drawn shall be filtered; and, second, to save the time required when the filter has to be filled by hand.

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[1] See fig. 9, p. 91.

Service-Filters for Land and Sea.—Col. Crease, C.B., Royal Marine Artillery, has arranged some excellent forms of filters, both small, for barrack, hospital, or ambulance use, and large tanks for ships or for large bodies of men on shore. The principle of them all is a filter of strong durable material, which yields nothing to water, space for a large quantity of filtering material, and a rapid delivery. The small filters may be earthenware or iron, the latter being protected internally by a patent cement;—the larger tanks of iron, protected in the same way.

Carbalite is now employed. By using a large quantity of the material, with a rapid delivery, a storage reservoir becomes unnecessary. The delivery can be regulated by screwing down or loosening a plate in the filter, so as to compress the material, or slacken the pressure as required.

The Filtre Rapide of Maignen is now used a good deal in the service, both for barrack and hospital use, and also in the field.[1] It has the advantage of enabling the filtering material to be frequently renewed and the asbestos strainer effectually cleaned by fire.

SECTION V.

SUB-SECTION I.—SEARCH AFTER WATER.

Occasionally a medical officer may be in a position in which he has to search for water. Few precise rules can be laid down.

On a plain, the depth at which water will be found will depend on the permeability of the soil and the depth at which hard rock or clay will hold up water. The plain should be well surveyed; and, if any part seems below the general level, a well should be sunk, or trials made with Norton's tube-wells. The part most covered with herbage is likely to have the water nearest the surface. On a dry sandy plain, morning mists or swarms of insects are said sometimes to mark water below. Near the sea, water is generally found; even close to the sea it may be fresh, if a large body of fresh water flowing from higher ground holds back the salt water. But usually wells sunk near the sea are brackish; and it is necessary to sink several, passing farther and farther inland, till the point is reached where the fresh water has the predominance.

Among the hills the search for water is easier. The hills store up water, which runs off into plains at their feet. Wells should be sunk at the foot of hills, not on a spur, but, if possible, at the lowest point; and if there are any indications of a water-course, as near there as possible. In the valleys among hills the junction of two long valleys will, especially if there is any narrowing, generally give water. The outlet of the longest valleys should be chosen, and if there is any trace of the junction of two water-courses, the well should be sunk at their union. In a long valley with a contraction, water should be sought for on the mountain side of the contraction. In digging at the side of a valley, the side with the highest hill should be chosen.

Before commencing to dig, the country should be as carefully looked over as time and opportunity permit, and the dip of the strata made out if possible. A little search will sometimes show which is the direction of fall from high grounds or a watershed.

If moist ground only is reached, the insertion of a tube, pierced with

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[1] A description of it is given in the Army Medical Regulations (1885), Appendix No. 9, p. 276.

holes, deep in the moist ground, will sometimes cause a good deal of water to be collected. Norton's American tube-well gave satisfaction in Abyssinia, although it did not succeed so well in Ashantee. A common pump will raise the water in it if the depth be not more than 24 or 26 feet; if deeper, a special force pump has to be used.

SUB-SECTION II.—SPECIAL CONSIDERATIONS ON THE SUPPLY OF WATER TO SOLDIERS.

In barracks and hospitals, and in all the usual stations, all that has to be done is to make periodical examinations of the quantity and quality of the water, to inspect the cisterns, &c., and to consider frequently if in any way wells or cisterns have been contaminated. As far as possible, a record should be kept at each station of the normal composition of the water.

In transport ships, the water and the casks or tanks should always be examined before going to sea. Should it show signs of putridity, distillation of sea-water, which is now easily managed, should be resorted to. If the water distils over acid, neutralise with carbonate of soda. If there is a little taste from organic mater, let it be exposed to the air for two or three days. Crease's tank-filters supply an excellent means of purifying water in large quantities. The spongy iron ship-filter is also an excellent form of filter for the purpose, and has the further advantage of removing lead should the water have taken any up during the process of distillation.

During marches each soldier carries a water-bottle.[1] He should be taught to refill it with good water whenever practicable. If the water is decidedly bad, it should be boiled with tea, and the cold tea drunk. The exhausted leaves, if well boiled in water, will give up a little more tannin and colouring matter, and will have a good effect; and if a soldier would do this after his evening meal, the water would be ready for the next day's march. Alum and charcoal should be used. Small charcoal or sandstone filters with elastic tubes (fig. 2) at the top, which draw water through like siphons, or through which water can be sucked, are useful, and are now much employed by both officers and men. They have been largely used by the French soldiers in Algiers, and some were issued to our troops both in the Ashantee and Soudan campaigns. It must be understood that these are all merely strainers, and do not purify the water from dissolved substances.

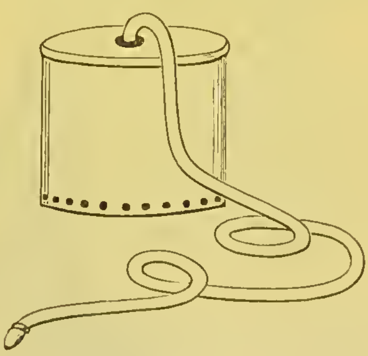

Fig. 2.

Soldiers should be taught that there is danger in drinking turbid water, as they will often do when they are overcome with thirst. Not only all sorts of suspended matters may be gulped down, but even animals. On some occasions the French army in Algiers has suffered from the men swallowing small leeches, which brought on dangerous bleeding. The pocket filters act fairly well in removing these suspended matters.

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[1] The Italian water-bottle has been officially adopted in our army, but it is doubtful if it has any advantage except its convenient shape. It certainly imparts an unpleasant taste to the water at first, and presents difficulty in cleaning. Probably an iron bottle (coated by the Bower-Barff process), covered with leather, would be better.

If water-carts or water-skins are used, they should be regularly inspected; every cart should have a straining filter of pure sand, through which the water should pass. The carts and skins should be scrupulously clean. The

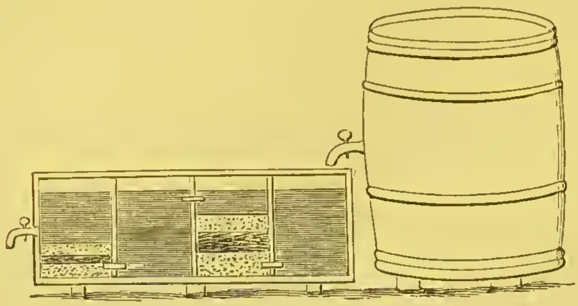

Fig. 3.

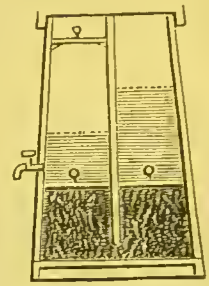

Fig. 4.

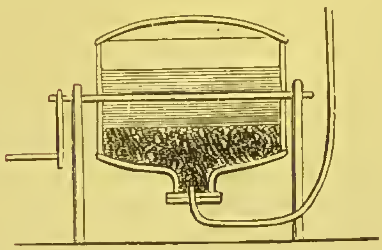

Fig. 5.

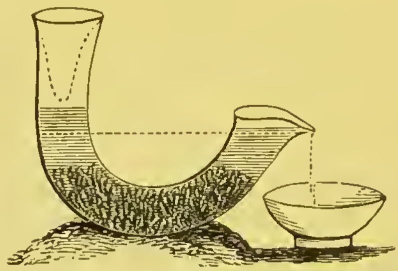

Fig. 6.

water-carriers, or bheesties, in India, should be paraded every morning, and the sources of water inquired into.

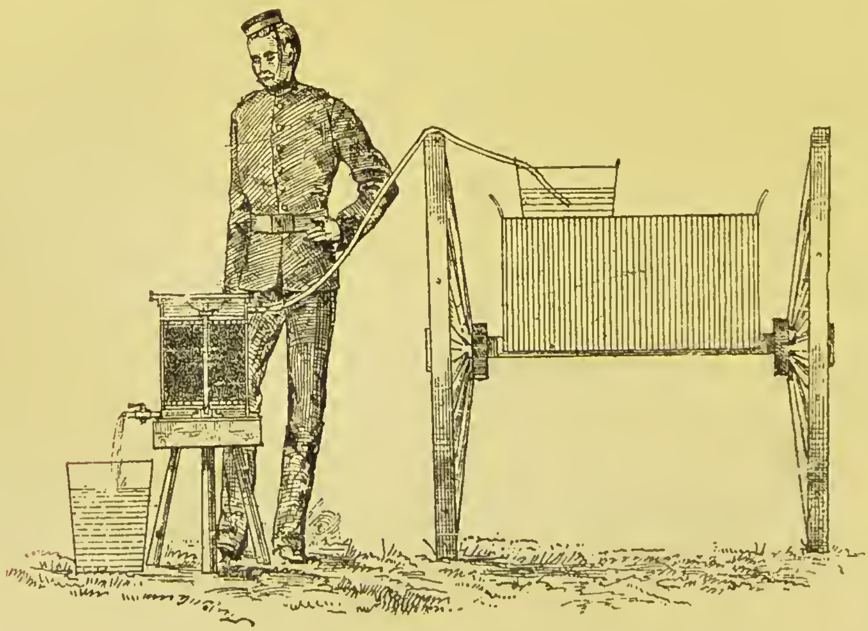

Fig. 7.

When halting ground is reached, it may be necessary to filter the water. A common plan is to carry a cask charred inside and pierced with small

holes at the bottom; it is sunk in a small stream, and the water rises through the holes. A better plan still is to have two casks, one inside the other, the outer pierced with holes at the bottom and the inner near the top; the space between is filled with sand, gravel, or any filtering medium that may

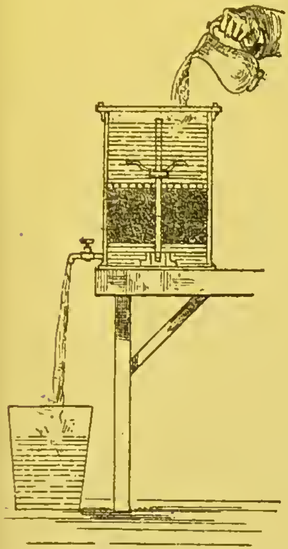

Fig. 8.

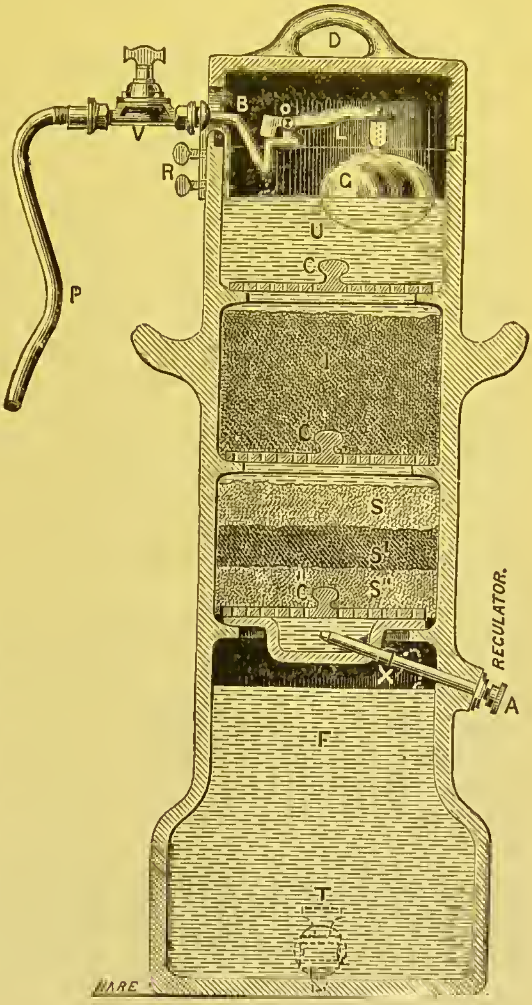

Fig. 9.[2]

be procurable; the water rises through the gravel between the barrels, and flows into the inner barrel.[1] The sand, gravel, or other material ought to be frequently turned out, cleaned, or changed. Other simple plans are given in the drawings, which need little description. Figs. 3 and 4 speak for themselves. Fig. 5 is a barrel connected by a pipe with a supply above; the water rises through sand and charcoal, and is drawn out above; the barrel is fixed on a winch, and, the supply pipe being removed, and the hole closed, a few turns of the handle clear the sand. Fig. 6 is a simple contrivance, which may be made of wood or tin. Figs. 7 and 8 show Crease's field-filter in use, either as a hand-filter (fig. 8) or connected by an india-rubber tube to a bucket

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[1] In the Zulu campaign Surgeon-General Woolfryes states that "to the large base hospitals, such as Fort Pearson and Utrecht, large single or double barrel (charcoal) filters made in Pietermaritzburg were furnished. For tho troops barrel (sand) filters, made on the spot by the Royal Engineers, were provided."—*A.M.D. Reports*, vol. xxi. p. 287.

[2] Fig. 9.—Spongy iron filter, special ball-cock pattern. A, cap of regulator; B, ball-cock; C, perforated lid, covering spongy iron; C', perforated lid, covering *prepared sand;* C", perforated plate, through which water flows to regulator; D, cover of filter; F, filtered water; G, glass ball; I, spongy iron; L, lever of ball-cock; O, withdrawing-pin of lever; P, tube connecting with water-supply or cistern; R, screws to fasten ball-cock to filter; S, pyrolusite; S', sand; S", fine gravel (these three form the *prepared sand*); T, tap or stop-cock, from which to draw the filtered water; U, unfiltered water; V, screw valve; X, division in regulator, from which XA may be screwed off; near X is the aperture through which the filtered water flows into the reservoir F.

of unfiltered water placed in a cart (fig. 7). It acts with great rapidity, and gives good results.[1]

Bearing in mind the results of mere agitation with rough particles of sand, scrap iron, &c., some such plan might be advantageously improvised in the field. A barrel mounted as in fig. 5 might be used as a revolver for the purpose, simulating the apparatus described by Mr W. Anderson as used at the Antwerp water-works.[2]

Maignen's field Filtre Rapide was used in the Egyptian campaign, and seemed to answer fairly well, but the strainer requires to be frequently cleansed and the filtering material renewed. Its portable form is an advantage.

In the field the medical officer may be sent on to give a report of the quantity and quality of any source. Before the troops arrive he should make his arrangements for the different places of supply; men and cattle should be watered at different points; places should be assigned for washing; and if removal of excreta by water be attempted, the excreta should flow in far below any possible spring; in the case of a spring several reservoirs of wood should be made, and the water allowed to flow from one to another—the highest for men, the second for cattle. If it is a running stream, localities should be fixed for the special purpose; that for the men's drinking water should be highest up the stream, for animals below, washing lowest; sentries should be placed as soon as possible. The distribution of water should be regulated; streams are soon stirred up, made turbid, and the water becomes undrinkable for want, perhaps, of simple management.

Wherever practicable the reservoirs or cisterns which are made should be covered in; even if it is merely the most flimsy covering, it is better than nothing.

In sieges the same general rules must be attended to. The distribution of the water should be under the care of a vigilant medical officer. Advantage should be taken of every rainfall; fresh wells should be dug early; if necessary, distillation of brackish or sea-water must be had recourse to.

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[1] In the Zulu campaign of 1879 Surgeon-General Woolfryes reports that "Crease's filters were used in the larger field hospitals, but were found unsuitable for field service, as they would not stand the rough usage incidental to the march."—*A.M.D. Reports*, vol. xxi. p. 287.

[2] *Journal of the Society of Arts*, Nov. 26, 1886, pp. 29 *et seq.*

CHAPTER III.

REMOVAL OF EXCRETA.

It is highly probable that to barbarous and inefficient modes of removing the excreta of men and of animals we must partly trace the great prevalence of disease in the Middle Ages, and there is no doubt that many of the diseases now prevailing in our large towns are owing to the same cause.

When men live in thinly-populated countries, following, as they will then do, an agricultural or nomad life, they will not experience the consequences of insufficient removal of excreta. The sewage matter returns at once to that great deodoriser, the soil, and, fertilising it, becomes a benefit to man, and not a danger. It is only when men collect in communities that the disposal of excreta becomes a matter literally of life and death, and before it can be settled the utmost skill and energy of a people may be taxed.

The question of the proper mode of disposal of sewage has been somewhat perplexed by not keeping apart two separate considerations. The object of the physician is to remove as rapidly as possible all excreta from dwellings, so that neither air, water, nor soil shall be made impure. The agriculturist wishes to obtain from the sewage its fertilising powers. It is not easy to satisfy both parties, but it will probably be conceded that safety is the first thing to be sought, and that profit must come afterwards.

SECTION I.

AMOUNT AND PRODUCTS OF THE SOLID AND LIQUID EXCRETA.

Amount of the Solid and Liquid Excreta.

The amount of the bowel and kidney excreta varies in different persons and with different modes of life. On an average, in Europe, the daily solid excreta are about 4 ounces by weight, and the daily liquid excreta 50 ounces by measure for each male adult. Women and children pass rather less. Vegetable pass more solid excreta than animal feeders, but this is chiefly owing to a large proportion of water.[1] Taking all ages and both sexes into consideration, we may estimate the daily amount per head of population in Europe at $2\frac{1}{2}$ ounces of fæcal and 40 ounces of urinary discharge. A population of 1000 persons would thus pass daily 156 lb of solids and 250 gallons of urine, or in a year 25 tons of fæces and 91,250 gallons (14,647 cubic feet) of urine. This gives 6·25 tons of water-free solids for the fæces and 16·7 from the urine, total 23 tons in round numbers, per annum. Letheby gives the mean daily amount per head as 2·784 ounces of fæces and 31·851 ounces of urine.

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[1] Mr Fawcus's experiments on Bengalee prisoners give an average bowel excretion of 12 ounces, and in Bombay Dr Hewlett found the alvine discharges to be quite as large.

Frankland estimates the mean daily amount per head as 3 ounces of fæces and nearly 40 ounces by measure of urine. In adult males the quantity of nitrogen daily discharged by the bowels and kidneys amounts to from 250 to 306 grains, representing 304 and 372 grains of ammonia. Taking the whole population, however, the amount must be considerably less than this. Dr Parkes calculated it as 153 grains of nitrogen, and Letheby gave it as 155·8 grains, or from 186 to 189 grains of ammonia, *i.e.*, the mean excretion of all the population is more than half the excretion of the adult male.

Decomposition of Sewage Matter.

Fresh healthy fæcal matter from persons on mixed diet, unmixed with urine, has an acid reaction, and this it retains for a considerable time; it then becomes alkaline from ammonia. If free from urine it usually decomposes slowly, and in hot weather often dries on the surface and subsequently changes but little for some time. The urine, when unmixed with fæcal matter, also retains its natural acidity for a variable number of days,—sometimes three or four, sometimes eight or ten, or even longer, and then becomes alkaline from ureal decomposition. When the fæces and urine are mixed, the formation of ammonium carbonate from ureal decomposition is much more rapid; the solid excreta seem to have the same sort of action as the bladder mucus, and the mixed excreta become alkaline in twenty-four hours, while the separate excreta are still acid. And in its turn the presence of the urine seems to aid the decomposition of the solid matter, or this may be perhaps from the effect of the liquid, as pure water seems to act almost as rapidly as urine in this respect. Pappenheim[1] states that the absorption of oxygen by the fæces is greatly increased when urine is added. When the solid excreta and urine are left for two or three weeks, the mixture becomes usually extremely viscid, and this occurs, though to a less extent, when an equal quantity of pure water takes the place of urine. The viscidity is prevented by carbolic acid.

When the solid excreta (unmixed with urine) begin to decompose, they give out very fœtid substances, which are no doubt organic; hydrogen sulphide is seldom detected, at any rate by the common plan of suspending paper soaked in lead solution above the decomposing mass. When heated, a large quantity of gas is disengaged, which is inflammable, and consists in great measure of carburetted hydrogen. When (instead of being dry) urine is present, ammonia and fœtid organic matters are disengaged in large quantity. When water is also present, and if the temperature of the air is not too low, not only organic matters but gases are given out, consisting of light carburetted hydrogen, nitrogen, and carbon dioxide. Hydrogen sulphide can be also disengaged by heat, and is almost always found in the liquid, usually in combination with ammonia, from which it is sometimes liberated and then passes into the air.

SECTION II.

METHODS OF REMOVAL OF EXCRETA.

While all will agree in the necessity of the immediate removal of excreta from dwellings, the best modes of doing so are by no means settled. The fact is that several methods of removing sewage are applicable in different

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[1] *Handb. der San. Pol.*, 2nd edit., Band i. p. 72.

circumstances, and their relative amounts of utility depend entirely on the condition of the particular place.

The different plans may be conveniently divided into [1]—

1. The water method.
2. The dry methods.

Before noticing these plans, it will be convenient to make a few general observations on sewers.

SEWERS.

Sewers are conduits employed to remove waste water and waste products suspended in water from houses, or to carry away rain. Among the waste products may be the solid and liquid excreta of men and animals, or the refuse of trade and factory operations. Or sewers may be used merely for the conveyance of dirty house-water, without the admixture of excreta or trade refuse.

It is quite impossible that any town or even any single large house can be properly freed of its waste house-water without sewers, and in more or less perfect condition they are to be found not only in all modern but in most ancient cities. Originally, no doubt, they were mere surface channels, as they are still in many towns; but for the sake of appearance and inoffensiveness, the custom must have soon arisen of placing them underground, nor in modern towns could they now be arranged otherwise. In some large towns there are even hundreds of miles of sewers constructed often with great skill and science, and they serve in some instances as the channels not only for rain, but for natural streams which have been enclosed.

The sewers form thus in the subsoil of towns a vast network of tubes, connecting every house, and converging to a common outlet where their contents may be discharged.

In some towns the sewers carry away none of the solid excreta, though probably urine enters in all cases. In most towns, however, solid excreta in greater or less quantity enter, owing especially to the prevalent use of water-closets, or to the drainage of middens and manure heaps.

Whether the solid excreta pass in or not, the liquid in the sewers must always contain either suspended or dissolved animal and vegetable matters derived from the refuse of houses. It is generally warmer than the water of streams, and is of no constant composition: sometimes it is very turbid and highly impure; in other cases it is hardly more impure than the water of surface wells. The suspended matters are, however, generally in larger proportion than the dissolved.

In some cases the sewer water is in greater amount than the water supplied to the town and the rainfall together. This arises from the subsoil water finding its way into the sewers.

One ton of London or Rugby sewage contains only from 2 ℔ to 3 ℔ of solid matter (Lawes).[2] One ton of Southampton sewage contains about 2 ℔ dissolved and $1\frac{1}{4}$ ℔ to $1\frac{1}{2}$ ℔ suspended matter.

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[1] Dr Corfield's work (*A Digest of Facts relating to the Treatment and Utilisation of Sewage*, by W. H. Corfield, 3rd edit., 1887) will be found to give a good summary of this subject. See also *Report of a Committee appointed by the President of the Local Government Board to inquire into the several modes of treating Town Sewage*, London, Eyre and Spottiswoode, 1876; see also "Die Menschliche Abfallstoffe," von Dr Ferd. Fischer, *Supplement zur Deutschen Viertelj. f. Offt. Gesundh.*, 1882; *Report of the Royal Commission on Metropolitan Sewage Discharge*, 1884.

[2] For the composition of sewer water, see Way, *Second Report of Common Sewage of Towns*, 1861, p. 69 *et seq.*; Letheby, *The Sewage Question*, 1872, p. 135; *Report on Town Sewage*, 1876; *Rivers Pollution Commissioners' Report*; *Report of Roy. Comm. Metr. Sew. Disch.*, 1884.

The average composition of sewer water in towns with water-closets is: organic matter, 39·6; nitrogen, 8·87; phosphoric acid, 2·24; potash, 2·9 parts per 100,000.[1]

The Rivers Pollution Commissioners give 7·28 parts of organic nitrogen per 100,000 parts, or 5·41 grains per gallon; the mean amount of ammonia is 6·703 per 100,000, or 4·692 grains per gallon.

Under the microscope, sewer water contains various dead decaying matters, and, in addition, multitudes of *Bacteria* and amœbiform bodies, as well as some ciliated infusoria, especially *Paramecia*. *Fungi* (spores and mycelium) are seen, but there are few *Diatoms* or *Desmids*, and not many of the higher animals, such as *Rotifera*.

A controversy is still going on whether the solid excreta ought to be admitted into the sewers. The point is virtually practically decided in many towns in this country by the general use of water-closets, which cannot now in these towns be superseded by any plan yet proposed. It is, however, quite an open question whether, if all the arrangements could be commenced *de novo*, the admission of the solid excreta would be proper.

The arguments for and against this view will presently be stated.

Whether the solid excreta are allowed to pass in or not, it is clear that the dirty water of the sewers must in some way be disposed of. It is in every case more or less impure, containing animal and vegetable substances in a state of commencing decay, which passes readily into putrefaction. The readiest mode of getting rid of it is to pass it into streams, where it is at once subjected to the influence of a large body of water, and where the solid matters become either slowly oxidised, or form food for fishes or water plants, or subside. Although from an early period streams were thus contaminated and their water, originally pure, was thus rendered unfit for use, it is only lately that a strong opposition has arisen to the discharge into streams. This is owing partly to the greater pollution and nuisance caused by the more common use of water-closets and the largely increasing trade of the country, which causes more refuse to be sent in, and partly to the evidence which has been brought forward of the diseases which are caused by drinking water made impure in this way. To prevent the nuisance and danger caused by the pollution of streams, many actions at law have been brought, and in some cases special Acts of Parliament have forbidden the discharge of sewer water into certain rivers until after efficient purification. The Rivers Pollution Act of 1876 now deals with the question, its provisions having come into operation on the 15th August 1877. Unfortunately, from various causes, it has been largely inoperative, and must ere long be reconsidered.

Up to a certain point there would probably be a general agreement as to the principle on which this difficult question should be dealt with. Animal substances in a state of decay can be best prevented from contaminating the air, the soil, or the water of streams by imitating the operations of nature. In the endless cycle of physical change, decaying animal matters are the natural food of plants, and plants again form the food of animals.

It so happens that, with the exception of some mineral trades, the waste products of which are hurtful to agriculture, many of the substances contained in the sewer water of our towns are adapted for the food of plants, and we seem on sure ground when we decide that it must be correct to

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[1] Letheby, *op. cit.*, p. 138.

submit these matters to the action of plant life, and thus to convert them from dangerous impurities into wholesome food.

The difficulty is, however, with the application of the principle, and at the present moment there is the utmost diversity of opinion on this point. It seems, however, that we may divide the opinions into two classes. According to one opinion, the proper mode is to bring the waste water of towns, when it contains fertilising matters, at once to the ground, and, after the arrest of substances which may block the pipes, to pour it over the land in such a way as may be best adapted to free it from its impurities and to bring it most rapidly and efficiently under the influence of growing plants.

The other opinion objects to this course on two grounds,—first, that the substances are not brought to the ground in the most convenient form for agriculture, and also that the plan entails evils of its own, arising from the immense quantity of water brought upon the land and from the difficulty of efficient management. The advocates of this second view would, therefore, use some plan of separating the impurities of the water, and would then apply them in a solid form to the land, or use them for some other purpose, as in General Scott's plan of adding the materials for cement and then making this substance. The purified water would then be filtered through land, or passed into streams, without further treatment.

In the case of the sewage water containing materials not adapted for agriculture, both parties would deal with it in the same way, viz., purify it by chemical agencies or filtration, and then allow the water to flow off into streams, while the solid products would be disposed of in the most convenient way.

These general views apply to any sewer water, whether it contains solid excreta or not, although if these excreta can be perfectly excluded the sewer water is less offensive, though not much so, when the volume of water is large. It has hitherto been often poured into streams without previous purification, though now this practice is prohibited by law, with certain reservations.

The sewers of a town are for the most part used also to carry off the rainfall, and, indeed, before the introduction of water-closets they were used only for this purpose, and for taking away the slop and sink water of houses. In countries with heavy rainfall, and in this country in certain cases, the rainfall channels are distinct from the sewers, and the outfalls may be in an entirely different direction. This is sometimes called the "separate system."

Removal of Excreta by Water.

This is the cleanest, the readiest, the quickest, and in many cases the most inexpensive method. The water supplied for domestic purposes, which has possibly been raised to some height by steam or horse power, gives at once a motive force at the cheapest rate; while, as channels must necessarily be made for the conveyance away of the waste and dirty water which has been used for domestic purposes, they can be used with a little alteration for excreta also. It would be a waste of economy to allow this water to pass off without applying the force which has been accumulated in it for another purpose.

But if this is obvious, it is no less so that certain conditions of success must be present, without which this plan, so good in principle, may utterly fail. These conditions are, that there shall be a good supply of water, good

sewers, ventilation, a proper outfall, and means of disposing of the sewer water. If these conditions cannot be united, we ought not to disguise the fact that sewers, improperly arranged, may give rise to no inconsiderable dangers. They are underground tubes, connecting houses, and allowing possibly, not merely accumulation of excreta, but a ready transference of gases and organic molecules from house to house, and occasionally also causing, by bursting, contamination of the ground, and poisoning of the water supply. And all these dangers are the greater from being concealed. It is probably correct, as has been pointed out, that in deep-laid sewers the pressure inwards of the water of the surrounding soil is so great as frequently to cause an overflow *into* the sewer, and so prevent the exit of the contents; but, in other cases, the damage to the sewer may be too great to be neutralised in this way, and, in the instance of superficially laid and choked-up pipes, the pressure outwards of the contents must be considerable. The dangers of sewers have now been greatly reduced, by having good material, better construction, good ventilation, sufficient water supply, and means of disposal of the sewage water.

Amount of Water for Sewers intended for Excreta.

Engineers are by no means agreed on the necessary amount. We have already named 25 gallons per head per diem, on the authority of Mr Brunel, as the amount required to keep common sewers clear, and even with this amount there should be some additional quantity for flushing. But in some cases a good fall and well-laid sewers may require less, and in other cases bad gradients or curves or workmanship may require more. It is a question whether rain-water should be allowed to pass into sewers; it washes the sewers thoroughly sometimes, but it also carries débris and gravel from the roads, which may clog; while in other cases storm waters may burst the sewers, or force back the sewage. To obviate this, storm overflows have to be provided; of these there are about fifty within the metropolitan area, to relieve the low-level sewers on both sides of the Thames.[1]

Construction of Sewers.

Sewers are differently constructed according to the purposes they are to serve, *i.e.*, whether simply to carry off house and trade water, or the solid excreta in addition, or one or both, with the rainfall.

In following out the subject, it will be convenient to trace the sewers from the houses to the outfall, after first considering the construction of water-closets.

Water-Closets and Water-Troughs.

Water-Closets.—The old pan closet is now, happily, being abandoned, although still to be found in many dwellings and public buildings. It consists of a conical pan surrounded by a container, and having at the bottom a small movable pan, usually of tinned copper, to receive the excreta; this holds a certain amount of water, and is intended to act as a water seal or trap. Frequently, from failure of water, defective apparatus, or from the copper being eaten through by oxidation (not uncommon when there are nitrates in the water supply), the pan is empty, so that free passage is given to noxious gases. Add to this that the container is

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[1] *Report on Metr. Sewage Discharge*, 1884. For description of storm overflows, see Bailey-Denton, *op. cit.*, sections lxii. and lxxxv.

always more or less filthy, and that the soil pipe from it usually terminates in a D trap, and we have one of the worst combinations from a sanitary point of view. All such closets ought to be definitively abolished.

In modern improved forms the pan of the closet is usually a cone in earthenware (which is better than metal), with a siphon or flap valve below. In addition, there are numerous contrivances for flushing the pan and siphon, and for preventing the escape of the air from the soil pipe into the house.[1] The soil pipe is usually of cast lead; but both lead and iron are easily eaten through, as shown by Drs Fergus and N. Carmichael, and earthenware pipes, if strong and well joined, would be preferable.[2]

The points to be looked to in examining closets are—1*st*, that the pan is nearly a cone, and not a half circle with a flat bottom; 2*nd*, that the amount and force of water is sufficient to sweep everything out of the siphon; 3*rd*, that the soil pipe is ventilated beyond the siphon by being carried up full-bore to the top of the house; 4*th*, that the junction of siphon and soil pipe and the lengths of the soil pipe are perfect.

With respect to water, a pipe from the house cistern frequently leads to the closet; but if so, there is danger of gas rising through the pipe. There should be a special small cistern for the use of the closet. What are termed water-waste preventers are now commonly used, fed either by a cistern or by constant supply. They are boxes which are emptied by a valve into the pan, and are then refilled. There are many kinds, but perhaps the best are those that work by siphon action, brought into play by pulling a wire. The amount of water should not be less than two gallons, and the fall should not be less than 3 or 4 feet, so as to insure thorough scouring of the soil pipe.[3]

The ventilation of the soil pipe is a matter of importance, as the water from the pan suddenly displaces a large body of foul air, which rises through the siphon as the water flows. The best plan is to carry up the soil pipe full-bore to the roof, far from any windows. It is well also to have a second pipe from the crown of the siphon to the ventilating pipe, in order to prevent the unsiphoning of the trap (see fig. 18). Air is supplied by a grating below, as in Buchan's and other disconnecting traps, or (as in Banner's plan) by drawing air from another shaft carried up the house. The currents in the two shafts are determined by reversed cowls. In some cases it is proposed to draw the air *down* the soil pipe and *up* another pipe.

The simple hopper closet, or some form of "wash-out" closet, with a siphon trap below, is the safest; but there are some good forms of valve closet in the market. They are, however, too frequently made with overflow pipes passing into the soil pipe. These, although siphon-trapped, are apt to be sucked dry. They are thus dangerous, and they are really unnecessary, for a well-made siphon pan rarely overflows. If it does, it is better to receive the overflow on to a safe under the closet, from which the water flows out through a pipe to the open air, such pipe acting as a warning pipe.

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[1] Mr Eassie's work, *Healthy Houses*, gives a good account of the various kinds of closets; see also his article in *Our Homes*.

[2] In his work on *Sanitary Arrangements for Dwellings*, Mr Eassie does not approve of earthenware pipes, preferring the strongest cast lead to any other.

[3] The Army Sanitary Committee (*On Sanitary Appliances*, Blue Book, 1871, p. 17) state that the amount of water used in the water-closets in the army is, for Green's closet, between ½ gallon and 1 gallon for each time of use; Underhay's, Lambert's, and the pan-closet, from 1 to 1½ gallon; and for Jenning's closet, usually the same, or in some stations 3 gallons. The quantity ought not to be less than 2 gallons under any circumstances.

The position of the closet is a matter of great moment. If possible, it should always be in an outbuilding, or a projection, with thorough ventilation between it and the house. In two-storied buildings it might be put in a small third story in the roof, and well ventilated above. The windows in a closet ought always to open quite to the ceiling.

In all cases, a tube should pass from the top of the closet to the outer air; and, if the closet is in a bad situation, the tube should be heated by a gas-jet.

It is a bad plan to have the pull-up handle covered by the lid;[1] it should be able to be pulled up when the lid is shut, or the shutting of the lid should open the water-waste preventer cistern. In wash-out closets the flush is often obtained by pulling a wire like a bell-pull, as mentioned above.

The plan of placing closets in the basement should be entirely given up; closet air is certain to be drawn into the house.

Water-Troughs or Latrines.—These are very strong earthenware or cast-iron elongated receptacles, which are about half full of water. The excreta drop into the water, and once or twice a day a valve is raised, and the water and excreta pass into a drain. There is usually a catch-pit into which fall bits of bricks, towels, or other things which are thrown in, so that they are stopped and fished out when the trough is emptied, and do not pass into the drain. The amount of water in the water-latrines used in some barracks is about 5 gallons per head daily, so that the plan is not economical of water, but, as it avoids all loss by the dripping in closets, there is probably no great excess of expenditure. It is a good plan to have a flexible hose attached to the water-pipe so as to wash thoroughly the seats and partitions every day.

The chief objection to this plan has been the labour which is necessary to empty the trough; but this may be obviated by the use of automatic flush tanks, discharging periodically. On the other hand, there is saving of expenditure in repairs to water-closets.[2]

In judging of the value of a water-trough, the amount of water, the surface exposed to evaporation, and the completeness of the flushing are the points to look to.

House Pipes and Drains.

It will be convenient to call the conduits inside the house, which run from sinks and closets, "house pipes," and to give the term "drain pipes" to the conduits which receive the house pipes, and carry the house water into tanks or main sewers. The house pipes may be divided into sink and water-closet or soil pipes; they are made of metal (lead, iron, or zinc, or two of these) or of earthenware. The drain pipes are usually made of well-burnt, hard, smooth glazed earthenware.[3] All bricks, porous earthenware, or substances of the kind should be considered inadmissible for drain pipes. Iron pipes are not much used in this country, but are common and in some places compulsory in America, when pipes have to be carried under houses.

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[1] In Dr Aldridge's patent the handle cannot be pulled up until the lid is shut down; there is also arrangement for carrying off foul gas by means of a pipe communicating with the outer air, the lid itself being air-tight round the rim of the seat.

[2] In the army two kinds of latrines (Macfarlane's of cast-iron, and Jenning's of earthenware) have been in use for many years. The army Sanitary Committee (*On Sanitary Appliances introduced into Barracks*, Blue Book, 1871, p. 14) state that out of 183 barracks only 53 were charged with repairs, and the average expenditure on these 53 was 12s. per barrack annually for Macfarlane's, and 18s. 9d. per barrack for Jenning's latrine, and nearly the whole of these expenses were caused by articles thrown carelessly into the latrines.

[3] Mr Baldwin Latham cautions us to see that the *socket* of the drain pipe is made with and is a component part of the pipe, and not merely joined on.

When made of heavy cast iron, jointed and well caulked with lead or Spence's metal, they are the best in many circumstances. Inside they may be enamelled, or coated with Dr Angus Smith's composition, or treated by Barff's process. The pipes and drains vary in size from 4 to 16 inches diameter,[1] but the usual size of stoneware pipes is 4 to 9 inches; they are round or oval in shape.[2]

Connection of House Pipes with the Drains.—It is customary to commence the drains at the basement of the house, and the sink and closet pipes pass down inside the house and join on, a water trap being placed at the junction.[3] As the aspiratory power of the warm house is then constantly tending to draw air through the water-trap, and as the trap is liable to get out of order, it is most desirable to alter this plan. The drains should end outside the house, and as far as possible every house pipe should pass outside and not inside or between walls to meet the drain. The object of this is that any imperfection in the pipe should not allow the pipe air to pass into the houses. At the junction of the house pipe and drain there should not only be a good

Fig. 10.—Jenning's Access-pipe.

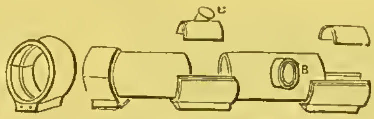

Fig. 11.—Stiff's Access-pipe and Junction.

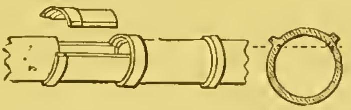

Fig. 12.—Doulton and Watt's Access-p'pe.

water-trap, but also complete ventilation and connection with the outside air at the point of junction. The rule, in fact, should be, that the union of any house pipe whatever with the outside drain should be broken both by water and by ventilation. In addition, it should be a strict rule that no drain pipe of any kind should pass under a house; if there must be a pipe passing from front to back, or the reverse, it is much better to take it above the basement floor than underneath, and to have it exposed

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[1] Pipes are made up to 36 inches and upwards, usually round up to 16 or 18 inches, and oval above that. Engineers are now desirous of restricting the term "drain" to a pipe that merely draws off moisture from land, using the term "sewer" for a pipe carrying sewage or liquid refuse of any kind. This distinction, however, has not been made in the Public Health Act of 1875, in which "drain" is used for the pipe that receives the "house pipes," and "sewer" for the main pipe of a system. (See Bailey-Denton's *Sanitary Engineering*, p. 16.)

[2] See Mr William Eassie's *Healthy Houses* (2nd edition) for much information on this and kindred subjects. Some of the drawings given here have been copied from Mr Eassie's work, by his permission; reference may also be made to *Sanitary Arrangements for Dwellings*, by the same author; also to *Our Homes, op. cit.*

[3] Builders are always anxious to conceal tubes, and thus carry them inside the walls, or, in the case of hollow walls, between the two. The consequence is that any escape of air must be into the house. The leakage of a closet pipe carried down in a hollow wall often constantly contaminates the air of the house. It would be infinitely better to run the pipes at once through the wall to the outside. Few persons have any idea of the carelessness of plumbers' work—of the bad junctions, and of the rapidity with which pipes get out of order, and decay. When a leaden pipe carrying water is led into a water-closet discharge pipe, it is frequently simply puttied in, and very soon the dried putty breaks away, and there is a complete leakage of gas into the house. Even if well joined, the lead pipe will, it is said, contract and expand, and thus openings are at last formed. Dr Fergus of Glasgow and Dr N. Carmichael have directed particular attention to this, in the case of lead closet pipes, which become easily perforated, and which have only a limited duration of wear. Considerable efforts are now being made (1886) by the Worshipful Company of Plumbers, in conjunction with others, to improve the general character of plumbers' work, and to secure the registration of competent workmen.

throughout its course. In such a case it ought to be of cast-iron, as already mentioned. In America this is made compulsory. It is hardly possible to insist too much on the importance of this rule of disconnection between house pipes and outside drains. Events have shown what a risk the richer classes in this country often run, who not only bring the sewers into the houses, but multiply water-closets, and often put them close to bed-rooms. The simple plan of disconnection, if properly done, would insure them against the otherwise certain danger of sewer air entering the house. Houses which have for years been a nuisance from persistent smells have been purified and become healthy by this means.

Cleansing of Pipes and Drains.—Pipes are cleaned by flexible bamboo or jointed rods with screws and rollers to loosen sediment. The safest plan of cleaning drains is from man-holes, the drains being laid in straight lines from man-hole to man-hole. By this means obstructions are easily detected and removed. The use of movable caps runs the risk of leakage, it being difficult to make the drain water-tight again after removing the cap, but with care such caps (see figs. 10 to 12) are useful with small pipes, where man-holes cannot be employed. Drain pipes should also be cleared out by regular flushing, carried out not less often than once a month. This is best done by means of an automatic apparatus such as Field's flush tank (fig. 13). By regulating the flow of water it may be made to empty itself as often as necessary.

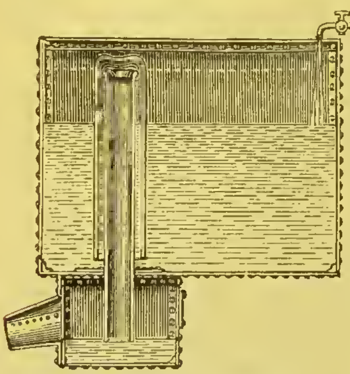

Fig. 13.—Field's Flush Tank.

Laying of Drains.—They should be laid very carefully on concrete in all soils. Sometimes, in very loose soils, even piling for the depth of a foot must be used besides the concrete. When pipes are not laid on a good foundation, leakage is sure to occur sooner or later, and the final expense is far more than the first outlay would have been. The greatest care must be taken in laying and joining the pipes, and in testing them afterwards, to make sure they are water-tight. In a wet soil, a good plan is to have a firm basis, or *invert block*, which is itself perforated to carry off subsoil water, and to put the drain over this, as in the plan of Messrs Brooks and Son of Huddersfield (see fig. 26).

The "junction" of pipes is accomplished by special pipes, known by the names of single and double squares, curved or oblique junctions, according to the angle at which one pipe runs into the other. The square junctions are undesirable, as blockage will always occur, and the oblique junctions should be insisted upon. When one pipe opens into another, a taper pipe is often used, the calibre being contracted before it enters the receiving pipe. All jointing must be in good cement, unless special patent joints (such as Stanford's) are used. Clay jointing is wholly inadmissible.[1]

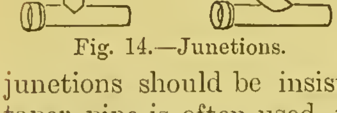

Fig. 14.—Junctions.

[1] Messrs Doulton and Son have introduced a new form of joint; the material is bituminous in character, like Stanford's, but instead of being fixed, the end of the spigot is slightly convex, whilst the surface of the faucet is slightly concave. We have thus a kind of ball-and-socket joint, which is water-tight, and yet permits considerable bending of the line of sewer without breaking and leaking. Of course, this is better than a sewer that breaks with accidental sinking of the ground, but it would certainly form deposit if allowed to bend in that way permanently.

Fall of Drain Pipes.—1 in 30 for 4-inch drains, and 1 in 40 for 6-inch; or, roughly, for small drains 1 inch per yard.

House-Traps.—As the traps are usually the only safeguard against the warm house drawing sewer air into it, the utmost attention is necessary to insure their efficiency. There is almost an infinite diversity, but they can be conveniently divided into the *siphon*, the *midfeather*, the *flap-trap*, and the *ball-trap*.

The *siphon* is a deeply-curved tube, the whole of the curve being always full of water. It is a useful trap, and efficient if the curve is deep enough, so that there is a certain depth of water (not less than ¾ inch) standing above the highest level of the water in the curve, and if the water is never sucked out of it, and if the pipe is not too small, so that the water is carried away, when it runs full, by the siphon action of the pipe beyond. If two siphons succeed each other in the same pipe, without an air opening between, the one will suck the other empty.

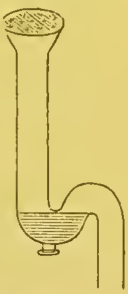

Fig. 15.—Siphon Sink Trap, with movable screw for cleaning.

The *midfeather* is in principle a siphon; it is merely a round or square box, with the entry at one side at the top, and the discharge pipe at a corresponding height on the opposite side, and between them a partition reaching below the lower margin of both pipes. Water, of course, stands in the box or receptacle to the height of the discharge, and therefore the partition is always to some extent under water. The extent should not be less than ¾ of an inch. Heavy substances may subside and collect in the box, from which they can be removed from time to time; but as ordinarily made it is not a good kind of trap, as it favours the collection of deposit, and is not self-cleaning. The common bell-trap, with its modifications, is a variety of the midfeather-trap, but it is so inefficient that it ought to be given up. The best kind of sink trap is the simple siphon, with a screw cap by which to clean it (fig. 15).

The *flap* is used only for some drains, and is merely a hinged valve which allows water to pass in one direction, but which is so hung as to close afterwards by its own weight. It is intended to prevent the reflux of water into the secondary drains, and is supposed to prevent the passage of sewer gas. But it is probably a very imperfect block.

The *ball-trap* is used in some special cases only; a ball is lifted up as the water rises, until it impinges on and closes an orifice. It is not a very desirable kind.

However various may be the form and details of the water-trap, they can be referred to one or other of these patterns.

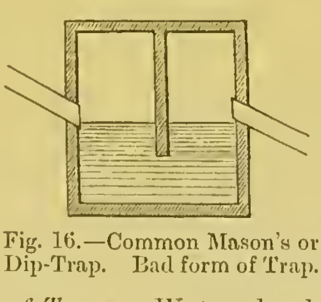

Fig. 16.—Common Mason's or Dip-Trap. Bad form of Trap.

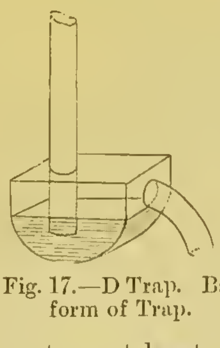

Fig. 17.—D Trap. Bad form of Trap.

Efficiency of Traps.—Water should stand in a trap at least ¾ of an inch above openings, and it should pass through sufficiently often and with sufficient force to clear it. An essential condition of the efficiency of all traps is that they should be self-cleansing. Many traps are so constructed that no amount or velocity of water can clear them. Such traps are the

common mason's or dip-trap (fig. 16), and the notorious D trap (fig. 17), both of which are simply cesspools, and could never be cleaned without being opened up. Such traps ought to be unhesitatingly condemned. Traps are often ineffective :—1*st*, From bad laying, which is a very common fault. 2*nd*, From the water getting thoroughly impregnated with sewer effluvia, so that there is escape of effluvia from the water on the house side. 3*rd*, From the water passing too seldom along the pipe, so that the trap is either dry or clogged. 4*th*, From the pipe being too small (2 or 3 inches only), and "running full," which will sometimes suck the water out of the trap; it usually occurs in this way, as frequently seen in sink traps; the pipe beyond the trap has perhaps a very great and sudden fall, and when it is full of water it acts like a siphon, and sucks all the water out of the trap; to avoid this, the pipe should be large enough to prevent its running full, or the trap should be of larger calibre than the rest of the pipe. This, however, will not always prevent it, as even 6-inch pipes have sometimes sucked a siphon dry. The question has lately been very carefully investigated, in America, by Messrs Philbrick and Bowditch,[1] whose report has shown the danger of unsiphoning which small pipes are exposed to. The remedy appears to be to introduce an air-vent at the crown of the trap (see fig. 18), and not to have too small a pipe, especially when several pipes unite in one general waste. The experiments also showed how unsiphoning might take place from the pressure of descending water from upper floors, so that air might be forcibly driven into the house when upper closets or sinks were used. Mr Glenn Brown's experiments show that with proper ventilation these dangers may be completely obviated.[2] 5*th*, Traps may perhaps be inefficient from the pressure of the sewer air, combined with the aspirating force of the house displacing the water, and allowing the air uninterrupted communication between the sewer and the house. The extent of the last danger cannot be precisely stated. From a long series of observations on the pressure of the air in the London sewers, Dr Burdon-Sanderson ascertained that in the main sewers, at any rate, the pressure of the sewer air, though greater than that of the atmosphere, could never displace the water in a good trap. In a long house drain which got clogged, and in which much development of gaseous effluvia occurred, there might possibly be for a time a much greater pressure, but whether it would be enough to force the water back, with or without the house suction, has not been yet experimentally determined. Dr Neil Carmichael has shown that water siphon traps act efficiently so long as they are not emptied by any siphon action beyond. But the reasons already given show that we ought

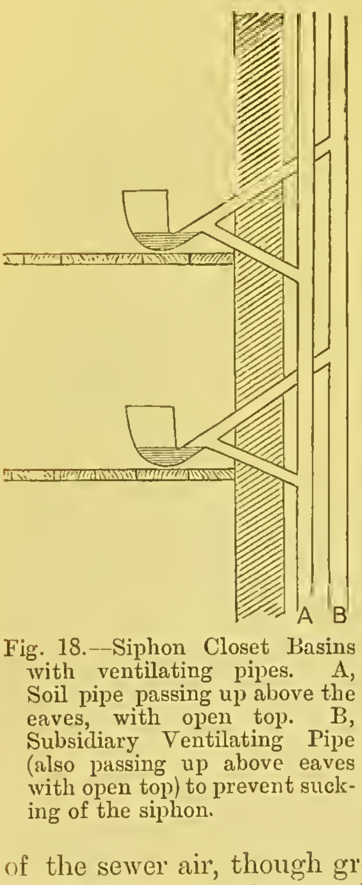

Fig. 18.—Siphon Closet Basins with ventilating pipes. A, Soil pipe passing up above the eaves, with open top. B, Subsidiary Ventilating Pipe (also passing up above eaves with open top) to prevent sucking of the siphon.

[1] *The Sanitary Engineer*, vol. vi. p. 264, 1882 (New York). "The Syphonage and Ventilation of Traps," *Report to the National Board of Health*, by E. W. Bowditch and E. S. Philbrick, C.E.

[2] *Report on Experiments in Trap Siphonage at the Museum of Hygiene, U.S. Navy Department, Washington, D.C.*, by Glenn Brown, Architect. Washington, 1886.

not to place dependence solely on traps,[1] though they are useful adjuncts. In arranging the house pipes the sink and water-waste pipes must not be carried into the closet soil pipes, but must empty in the open air over a grating.[2] See fig. 19. In the case of soil or water-closet pipes there must be also a complete air-disconnection between the pipe and drain by means

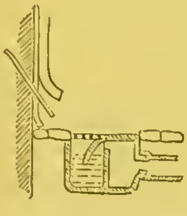

Fig. 19.—Pipes opening above Grating and Trap.

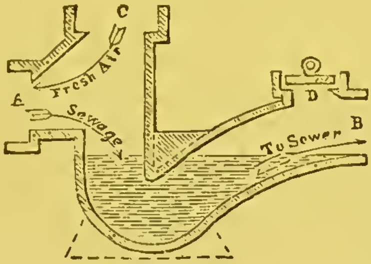

Fig. 20.—Disconnecting and Ventilating Drain Trap No. 2, Buchan's Patent.

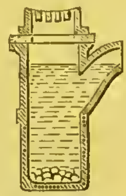

Fig. 21.—Simple Gully Trap.

of one of the contrivances now used by engineers. At the point where this disconnection is made there ought to be some easy means of getting at it for inspection.

A simple good form is Buchan's trap (fig. 20). A good form of man-hole

Disconnecting Man-hole.

Perforated Iron Door.

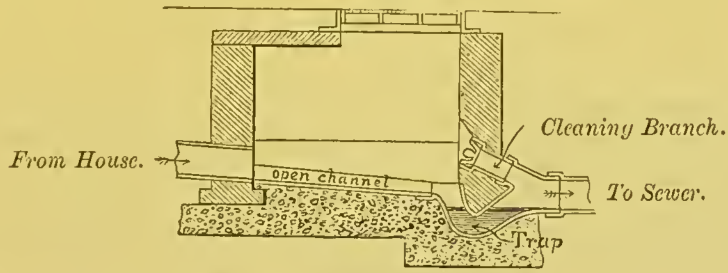

Fig. 22.—Longitudinal Section.

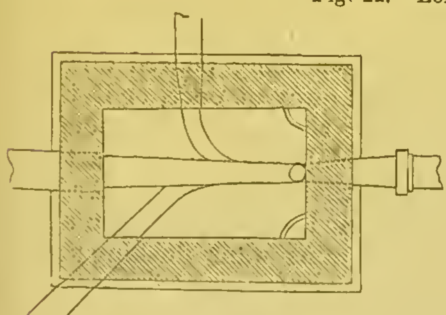

Fig. 23.—Plan.

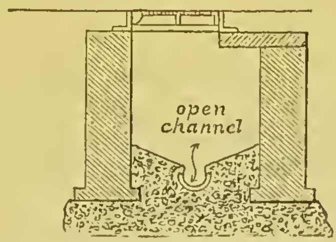

Fig. 24.—Cross Section.

is Mr Rogers Field's (see figs. 22 to 24).[3] Professor Reynolds[4] has suggested an arrangement which seems fairly good and simple.

A simple trap is sometimes made by inserting a pipe in the centre of a

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[1] "Honestly speaking, traps are dangerous articles to deal with; they should be treated merely as auxiliaries to a good drainage system."—*Eassie.*

[2] For the sake of appearance, in some cases, it may be necessary to carry the pipe immediately *under* the grating, but care must be taken that nothing occurs to obstruct the free communication with the open air through the grating.

[3] From Mr Field's *Bye-Laws for Uppingham,* with later improvements. I am indebted to Mr Field for several valuable suggestions.—[F. de C.]

[4] *Sewer Gas,* by Osborne Reynolds, M.A., Professor of Engineering at Owens College, Manchester, 2nd edition, 1872.

siphon, and carrying this pipe to the surface, or higher if considered desirable. It is, however, apt to be clogged with grease, fæces, and other light matter rising into the pipe. There are various similar arrangements. The "Somerset Patent Trap," designed by Mr Honeyman, and much used at Glasgow, is a midfeather-trap with an air-shaft on each side the partition; on one side the shaft ventilates the pipe leading to the sewer, on the other allows fresh air to pass into the house pipe. This second shaft also allows the trap to be cleaned.

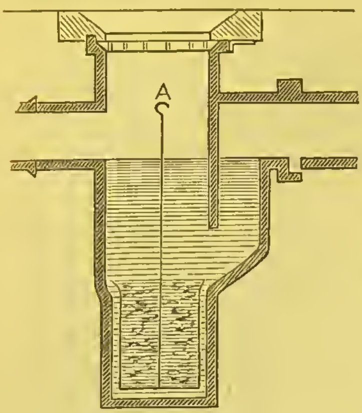

Fig. 25.—Dean's Gully Trap. A, Handle of movable bucket.

Rain-water pipes are sometimes used to ventilate drains, but, independent of their small size, which often leads to blockage, they are often full of rain, and cannot act at the time when ventilation is most required. They are also apt to deliver sewer gas into garret windows. The plan is objectionable, and ought to be abandoned.

A good form of disconnecting trap for sink and slop waters is Dean's, which has a movable bucket for removing deposits (fig. 25).

In yards, gully traps of different kinds are used, the action of which will be at once understood from the drawing (fig. 21).

Examination of House Pipes and Traps.

Pipes and traps are generally so covered in that they cannot be inspected; but this is a bad arrangement. If possible, all cover and skirting boards concealing them should be removed, and the pipe and trap underground laid bare, and every joint and bend looked to. But supposing this cannot be done, and that we must examine as well as we can in the dark, so to speak, the following is the best course:—Let water run down the pipe, and see if there is any smell; if so, the pipe is full of foul air and wants ventilation, or the trap is bad. If a lighted candle, or a bit of smouldering brown paper, is held over the entrance of the pipe or the grating over a trap, a reflux of air may be found with or without water being poured down. It should be noticed, also, whether the water runs away at once, or if there is any check. This is all that can be done inside the house; but though the pipe cannot be disturbed inside, it may be possible to open the earth outside, and to get down to and open a drain; in that case, pour water mixed with lime down the house pipe; if the whitened water is long in appearance, and then runs in a dribble merely, the drains want flushing; if it is much coloured and mixed with dirt, it shows the pipes and trap are foul, or there is a sinking or depression in some part of the drain where the water is lodging. The pipe should then be flushed by pouring down a pailful of lime and water till the lime-water flows off nearly clear. The drain should also be blocked, and water poured into the house pipe to see if it be water-tight in every part.

Yard-traps are often very foul, and if the trap-water be stirred, gas bubbles out, which is a sign of great foulness or that the traps are seldom used.

Main Sewers.

The outside house drain ends in a channel which is common to several drains, and is of larger size. These larger sewers are made either of round glazed earthenware pipes from 15 to 24 inches diameter, or of well-burnt

impervious brick moulded in proper curved shape and set in Portland cement, or stoneware bricks are partly used. The shape now almost universally given, except in the largest outfall part, is that of an egg with the small end downwards, so that the invert is the narrowest part. The object of this is to secure the maximum scouring effect with a small quantity of water. Engineers take the greatest care with these brick sewers; they are most solidly put together in all parts, and are bedded on a firm unyielding bed. Much discussion has taken place as to their size, but the question is so complicated by the admission of rain water, that it is difficult to lay down any fixed rule, at least as regards the main pipes. All other sewers, however, should be small, and with such a fall as to be self-cleansing.

Sewers should be laid in as straight lines as possible, with a regular fall; tributary sewers should not enter at right angles, but obliquely; and if the sewer curves, the radius of the curve should not be less than 10 times the cross sectional diameter of the sewer. Sometimes there is an arrangement for subsoil drainage under a pipe drain, as in the plan proposed by Mr Brooks.

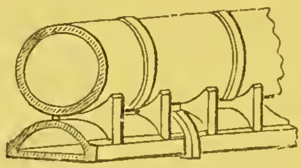

Fig. 26.—Brooks's combined Drain and Subsoil Pipe.

The fall for street drains is usually from 1 in 244 to 1 in 784, according to the size of the drain. The flow through a sewer should in no case be less than 2 feet per second, and 3 is better. As in the house drain, the fall should be equable without sudden changes of level.[1]

Access to Sewers.

It is of importance that, to all sewers capable of being entered by a man, there should be an easy mode of access. Man-holes opening above, or, what is better, at the side, should be provided at such frequent intervals, that the sewers can be entered easily and inspected at all points. The man-holes are sometimes provided with an iron shutter to prevent the sewer air passing into the street, or by the side of the man-hole there may be a ventilating chamber.[2]

Calculation of Discharge from Sewers.[3]

Several formulæ have been given, of which the following is the most simple:—

[1] In some cases a fall is almost impossible to obtain, as, for instance, at Southport, in Lancashire, where the ground is nearly a dead level. The fall there is about 1 in 5000, and never exceeds 1 in 3000. In such a case the drain would have to be cleaned either by locks or valves (flushing-gates) to retain a portion of the contents for a time, and then set them free suddenly in order to flush the next section, or by special arrangements, such as Field's flush-tank, or Shone's ejector.

[2] Mr Baldwin Latham joins the sewers in man-holes, so that if one is blocked another may be used; the outlet being at the lower level.

[3] The following table, taken from Mr Wicksteed, will be found useful:—

Sewers.

Diameter.	Velocity in feet per minute.	Gradient required.
4 inches	240	1 in 36
6 ,,	220	1 ,, 65
8 ,,	220	1 ,, 87
9 ,,	220	1 ,, 98
10 ,,	210	1 ,, 119
15 ,,	180	1 ,, 244
18 ,,	180	1 ,, 294
21 ,,	180	1 ,, 343
24 ,,	180	1 ,, 392
30 ,,	180	1 ,, 490
36 ,,	180	1 ,, 588
48 ,,	180	1 ,, 784

$V = 55 \times (\sqrt{D \times 2F})$.
V = velocity in feet per minute.
D = hydraulic mean depth.
F = fall in feet per mile.

Then, if A = section area of current of fluid, VA = discharge in cubic feet per minute.

To use this formula, the hydraulic mean depth when the sewage is flowing, and the amount of fall in feet per mile, must be first ascertained. The hydraulic mean depth is always $\frac{1}{4}$th the diameter in circular pipes;[1] in pipes other than circular it is the section area of current of fluid divided by the wetted perimeter. The wetted perimeter is that part of the circumference of the pipe wetted by the fluid. The fall in feet per mile is easily obtained, as the fall in 50 or 100 or 200 feet can be measured, and the fall per mile calculated (5280 feet = 1 mile).[2]

Movement of Air in the Sewers, and Ventilation.

It seems certain that no brick sewer can be made air-tight; for on account of the numerous openings into houses, or from leakage through brickwork, or exit through gratings, man-holes, and ventilating shafts, the air of the tubes is in constant connection with the external air. There is generally, it is believed, a current of air with the stream of water, if it be rapid. The tension of air in main sewers is seldom very different from that of the atmosphere, or if there be much difference equilibrium is quickly restored. In twenty-three observations on the air of a Liverpool sewer, it was found by Drs Parkes and Burdon-Sanderson[3] that in fifteen cases the tension was less in the sewer than in the atmosphere outside (*i.e.*, the outside air had a tendency to pass in), and in eight cases the reverse; but on the average of the whole there was a slight indraught into the sewer. In the London sewers, on the other hand, Sanderson noticed an excess of pressure in the sewers.

Mr Latham (*Lectures on Sanitary Engineering*, delivered to the Royal Engineers at Chatham) gives a table, of which the following is an extract:—

Diameter in inches.	Rate of inclination for velocity per second.				
	2 feet.	3 feet.	4 feet.	5 feet.	6 feet.
4	1:194	1:92	1:53	1:34	1:24
6	292	137	80	51	36
8	389	183	106	69	48
9	437	206	119	77	54
10	486	229	133	86	60
12	583	275	159	103	72

In this table the velocity in feet multiplied by the inclination equals the length of the sewer to which the calculation applies. For example, if the velocity is 6 feet per second in a pipe whose diameter is 4 inches, then $6 \times 24 = 144$ feet is the length of the sewer.

[1] This may be shown thus: Let r = the radius of section: then the perimeter $= \pi 2r$, and the section of fluid (or area of circle) $= \pi r^2$, then $\frac{\pi r^2}{\pi 2r} = \frac{r}{2}$, *i.e.*, $\frac{1}{2}$ the radius or $\frac{1}{4}$ the diameter.

[2] An example may illustrate the formula: Let the sewer be 12 inches in diameter and circular in shape; then the hydraulic mean depth is 3 inches or 0·25 of a foot; let the fall in feet per mile be 73: then we have $55 \times \sqrt{\cdot 25 \times 146} = 333$ feet per minute velocity; then the sectional area of the pipe running full = 0·7854 of a square foot, and $0{\cdot}7854 \times 333 = 261$ cubic feet discharged per minute.

[3] *Report on the Sanitary Condition of Liverpool*, 1870, p. 27.

If at any time there is a very rapid flow of water into a sewer, as in heavy rains, the air in the sewer must be displaced with great force, and possibly may force weak traps; but the pressure of air in the sewers is not appreciably affected by the rise of the tide in the case of seaboard towns.[1] The tide rises slowly, and the air is displaced so equably and gradually through the numerous apertures, that no movement can be detected. It is not possible, therefore, that it can force water-traps in good order, when there are sufficient ventilating apertures.

On the contrary, the blowing off of steam, or the discharge of air from an air-pump (as in some trade operations), greatly heightens the pressure, and might drive air into houses. So also the wind blowing on the mouth of an open sewer must force the air back with great force.

It is, therefore, important to protect the outfall mouth of the sewer against wind by means of a flap, and to prohibit steam or air being forced into sewers.

To how great an extent it is the openings into houses which thus reduce the tension of the air in main sewers is difficult to say, but there can be little doubt that a large effect is produced by houses which thus act as ventilating shafts.

When a sewer ends in a *cul-de-sac* at a high level, sewer gas will rise and press with some force; at least in one or two cases, the opening of such a *cul-de-sac* has been followed by so strong a rush of air as to show that there had been considerable tension. It is also highly probable, from the way in which houses standing at the more elevated parts of sewers, and communicating with them, are annoyed by the constant entrance of sewer air, while houses lower down escape, that some of the gases may rise to the higher levels.

That no sewer is air-tight is certain, but the openings through which the air escapes are often those we should least desire. It is therefore absolutely necessary to provide means of exit of foul and entrance of fresh air, and not to rely on accidental openings. The air of the sewer should be placed in the most constant connection with the external air, by making openings at every point where they can be put with safety. In London there are numerous gratings which open directly into the streets, and this plan, simple and apparently rude as it is, can be adopted with advantage whenever the streets are not too narrow. But in narrow streets the sewer gratings often become so offensive that the inhabitants stop them up. In such cases there must be ventilating shafts of as large a diameter as can be afforded, running up sufficiently high to safely discharge the sewer air.[2] In some of these cases it may be possible to connect the sewers with factory chimneys.[3] The sewer should never be connected with the chimneys of dwelling-houses.

In making openings in sewers it seems useless to follow any regular plan. The movement of the sewer air is too irregular to allow us to suppose it can ever be got to move in a single direction, though probably the most usual course of the air current is with the stream of water, if this be rapid. The

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[1] *Vide* same *Report*, p. 21, for the case of Liverpool. Dr Corfield's observation at Scarborough was confirmatory.

[2] In Liverpool there were small shafts with Archimedean screws at the top. From the observations of Sanderson and Parkes, it appears that these screws did act, but not to such an extent as to warrant the expense.

[3] It seems inadvisable to erect chimneys and use fires with an idea of ventilating the sewers on a general plan; the air would simply be drawn with great force through the nearest opening. But local ventilation by a factory chimney, when gratings cannot be used, is a different thing.

openings should be placed wherever it can conveniently be done without creating a nuisance. Some of these openings will be inlets, others outlets, but in any case dilution of the sewage effluvia is sure to be obtained. Sir R. Rawlinson considers that every main sewer should have one ventilator every 100 yards, or 18 to a mile, and this should be a large effective opening.[1]

But there may be cases when special appliances must be used. For example, in what are called "sewers of deposit," as when the outflow of the sewer water is checked for several hours daily by the tide or other causes, it may be necessary to provide special shafts, and the indication for this will be the evidence of constant escape of sewer air at particular points.

The use of *charcoal trays* has not answered the expectations that were formed of them.

Inspection of Sewers.

The inspection of sewers is in many towns a matter of great difficulty, on account of the means of access being insufficient, and also because the length of the sewers is so great. Still inspection is a necessity, especially in the old flat sewers, and should be systematically carried out, and a record kept of the depth of water, the amount of deposit, and of sewer-slime on the side or roof.

Choking of and Deposits in Sewers—Causes.—Original bad construction; too little fall; sharp curves; sinking of floor; want of water; check of flow by tides, so that the heavy parts subside.

Well-made sewers with a good supply of water are sometimes self-cleansing, and quite free from deposit, but this is, unfortunately, not always the case.

Even in so-called self-cleansing sewers, it has been noticed by Sir R. Rawlinson that the changing level of the water in the sewers leaves a deposit on the sides, which, being alternately wet and dry, soon putrefies. In foul sewers a quantity of slimy matter collects on the crown of the sewers; it is sometimes 2 to 4 inches in thickness, and is highly offensive. When obtained from a Liverpool sewer by Dr Parkes and Burdon-Sanderson, it was found alkaline from ammonia and containing nitrates.[2] On microscopic examination, this Liverpool sewer-slime contained an immense amount of fungoid growth and *Bacteria*, as well as some *Confervæ*. There were also *Acari* and remains of other animals and ova.

When deposits occur, they are either removed by the sewer-men or they are carried away by flushing of water.

Flushing of Sewers.—This is sometimes done by simply carrying a hose from the nearest hydrant into the sewer, or reservoirs are provided at certain points which are suddenly emptied. The sewer water itself is also used for flushing, being dammed up at one point by a flushing gate, and when a sufficient quantity has collected the gate is opened.[3] An automatic system is however preferable, such as is carried out by Field's annular siphon, before mentioned, or by Shone's ejector.

Almost all engineers attach great importance to regular flushing, and

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[1] Others have recommended 1 in 50 yards.

[2] *Report on the Sanitary State of Liverpool*, by Drs Parkes and Burdon-Sanderson, 1871. The amount of free ammonia was 25 parts per 100,000; the albuminoid ammonia was 4·62 per 100,000, and the nitric acid 203·5 per 100,000. Photographs are given of the microscopic appearances of the slime in this report.

[3] Baldwin Latham points out that there is a point of flow in all sewers when they discharge more than when running full. A good flushing power may be obtained at considerably less than the full discharge. Tables are given in his *Sanitary Engineering*.

almost the only advantage of allowing the rain to enter the sewers is the scouring effect of a heavy rainfall which is thus obtained. This, however, is so irregular that it is but a doubtful benefit.

Disposal of the Sewer Water.

The great engineering skill now available in all civilised countries can ensure in the case of any new works that the construction of sewers shall be perfect. If an engineer can obtain good materials, good workmen, and a proper supply of water, there is no doubt that sewers can be so solidly constructed and so well ventilated that the danger of deposits in the sewers, or of sewer air entering and carrying disease into houses, is removed.

But the difficulty of the plan of removing excreta by water really commences at the outfall. How is the sewer water to be disposed of?

This difficulty is felt in the case of the foul water flowing from houses and factories without admixture of excreta almost as much as in sewer water with excreta. The exclusion of excreta from sewers, as far as it can be done, would not solve the problem—would, indeed, hardly lessen its difficulty. In seaboard towns the water may flow into the sea, but in inland towns it cannot be discharged into rivers, being now prohibited by law. Independent of the contamination of the drinking water, the sewer water often kills fish, creates a nuisance which is actionable, and in some cases silts up the bed of the stream. It requires in some way to be purified before discharge. At the present moment the disposal of the sewer water is the sanitary problem of the day, and it is impossible to be certain which of the many plans may be finally adopted. It will be convenient to briefly describe these plans.

1. *Storage in Tank, with Overflow.*

The sewer water runs into a cemented tank with an overflow-pipe, which sometimes leads into a second tank similarly arranged. The solids subside, and are removed from time to time; the liquid is allowed to run away. Instead of letting the liquid run into a ditch or stream, it has been suggested to take it in drain pipes, ½ to 1 foot under ground, and so let it escape in this way into the subsoil, where it will be readily absorbed by the roots of grasses. The fat, grease, and coarser solids may be intercepted by a strainer, and daily removed and mixed with earth. The liquid portions may be discharged periodically by means of the automatic flush-tank.[1] In a light soil this could no doubt be readily done; and, if the drain pipes are well laid, a considerable extent of grass land could be supplied by this subterranean irrigation. The tank plan is, however, only adapted for a small scale, such as a single house or small village, and there should be ventilation between the tank and the house in all cases. This plan is applicable to the disposal of slop waters in villages, even when the excreta are dealt with by dry methods.

2. *Discharge at once into Running Water.*

All new works of this description are now prohibited, and the plan will probably ultimately cease in this country.[2]

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[1] See Mr Rogers Field's evidence, *Annual Conference on the Progress of Public Health at the Society of Arts*, 1880.

[2] When the sewer water passes into a river it undergoes considerable purification by subsidence, by the influence of water plants, and in a lesser degree by oxidation. Although some oxidation of nitrogenous organic matters into nitrous and nitric acids and ammonia

3. *Discharge into the Sea.*

The outlet pipe must be carried to low water, and, if possible, should be always under water. A tide flap opening outwards is usually provided. If not under water constantly, special care must be taken to prevent the wind blowing up the sewers. The tide will fill the outfall sewers (which are generally made large) to the level of high water, and to that extent will check the discharge, and in the sewers filled with the mixed sea-water and sewage there will be deposit. To remove this special attention is necessary.

If the sewage cannot be got well out to sea, and if it issues in narrow channels, it may cause a nuisance, and may require to be purified before discharge. In the Rivers Pollutions Act (1876) power is given to prohibit discharge into the sea or tidal waters under certain circumstances.[1]

4. *Precipitation.*

Another plan is not to pour the whole sewage into rivers, but to precipitate the solid part, or the greater portion of it, and then to allow the liquid to pass into the stream or over the land.

This is sometimes done by simple subsidence, the sewage being received into settling reservoirs or trenches, with strainers to arrest the flow to some extent. When the solid matter has collected to a certain amount, the sewage is turned into another reservoir, and the thick part, being mixed with coal refuse or street sweepings, is sold as manure.

The thin water which runs off must be almost as dangerous as the sewage itself when poured into streams, and consequently the prohibition to discharge sewer water extends to it also.

In order to produce greater purification, the sewage in the subsiding tanks is now usually mixed with some chemical agents which may precipitate the suspended matters.

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must take place, it appears from Frankland's experiments[2] that in the river Irwell, which receives the sewage of Manchester, after a run of 11 miles, and falling over six weirs, there is no formation of nitrites and nitrates, and there is even an increase in the organic nitrogen (?), though the suspended matters are less (from 2·8 to 1·44 parts per 10,000) than at first. Average London sewage diluted with 9 parts of water and siphoned from one vessel into another so as to represent a flow of 96 and 192 miles, gave a percentage reduction in the organic nitrogen of 28·4 and 33·3 respectively. The oxidation of sewage appears, then, from these experiments, to take place slowly. These experiments were, however, not conclusive. Odling does not think a long flow necessary for sewage oxidation. On this subject see the *Report of the Metropolitan Sewage Discharge Commission*, evidence of Odling, Frankland, Tidy, Abel, &c. Dr Letheby considers that oxidation takes place more rapidly, and that if sewage is mixed with 20 times its bulk of water, and flows for 9 miles, it will be perfectly oxidised.[3] Of course it is clear that ova, and solid parts of the body, like epithelium, might be totally unchanged for long periods,[4] and we may conclude that oxidation of sewage in running water cannot be depended on for perfect safety.

1 The word "stream" (into which sewage is not to be passed) is defined by section 20 of the Act, thus :—"Stream includes the sea to such extent and tidal waters to such point as may, after local inquiry and on sanitary grounds, be determined by the Local Government Board, by order published in the *London Gazette*. Save as aforesaid, it includes rivers, streams, canals, lakes, watercourses, other than watercourses, at the passing of this Act. mainly used as sewers, and emptying directly into the sea or tidal waters, which have not been determined to be streams within the meaning of this Act by such order as aforesaid."

2 *Reports of the Commissioners appointed to inquire into the Pollution of Rivers*, 1870, vols. i. ii. and iii.

3 *Report of East London Water Bill Committee* (1867), p. 430, questions 732–4.

4 As formerly mentioned, Dr Parkes found unchanged epithelium in unfiltered Thames water after a transit in a barrel of 80 miles, and after keeping for five months. It was transparent and worn, but quite recognisable.

Numerous substances have been employed as precipitants.[1]

Lime Salts.—Quicklime (proportion 8 to 12 grains per gallon), or 1 ℔ of lime for 600 gallons of sewage (nearly); chloride of lime, which is added to quicklime in the proportion of about $\frac{1}{40}$th part of chloride to 1 of lime; calcic phosphate dissolved in sulphuric acid, or a mixture of mono- and di-calcic phosphate with a little lime (Whitthread's patent),[2] are said to be good precipitants. Chloride of calcium has also been recommended.

Aluminous Substances.—Aluminous earth mixed with sulphuric acid (Bird's process); impure sulphate of aluminum (Anderson's and Lenk's processes); refuse of alum-works, either alone or mixed with lime or charcoal; clay mixed with lime (Scott's cement process); natural phosphate of aluminum dissolved by sulphuric acid and mixed with lime. In all these cases the amount of the substance added is from 50 to 80 grains per gallon of sewer water.

Magnesian salts mixed with lime in the form of superphosphates (Blyth); impure chloride of magnesium.

Black-ash waste, the residue from the manufacture of washing soda (sodium carbonate), has been tried, with the addition of a little lime (Hanson's patent).[3] It is used in Aldershot (town) and in other places.

Carbon in the shape of vegetable charcoal; peat; sea-weed charcoal; carbonised tan; lignite; Boghead coke; so-called porous carbon.

Iron in the shape of sulphate; perchloride (Ellerman's and Dale's liquid); the sulphate is sometimes mixed with lime and coal-dust. Iron is also sometimes added to lime.

Manganese.—Condy's fluid; manganate of soda.

Zinc sulphate and chloride.

The deposit obtained from these processes is sometimes collected and dried on a hot floor, a stream of hot air being allowed also to pass over it. There is some little difficulty in drying it, but this is now being overcome. The sludge, after precipitation with lime, in Birmingham is spread upon the ground and dug in when partially dry. One acre a week is used, upon which 500 tons of sludge a day are put. It is then cropped for three years before being again used. At Leyton, Wimbledon, and elsewhere the sludge, which contains 90 per cent. of water, is pressed in patent presses until it contains only 45 per cent of moisture. It is then in the form of solid dry-looking cakes, which may be taken for laying on land, making cement, &c. At Southampton porous carbon is used to the extent of 4 grains a gallon, the effluent is expelled into the river by a Shone's ejector, and the sludge by a similar process is projected to the corporation works, where it is mixed with road sweepings and ashes. This mixture finds a sale at 2s. 6d. a ton among the farmers in the neighbourhood.[4] In general the deposit appears to possess small agricultural value,[5] although it is

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[1] An interesting account of the precipitating process is given in a book called *The Sewage Question*, the author of which has had the advantage of Dr Letheby's notes and analyses. A list of no less than 57 processes or proposals is given at page 38, from which it appears that the first precipitant was proposed by Deboissieu so long ago as 1762, and was a mixture of acetate of lead and proto-sulphate of iron.

[2] This patent was found to give good results in removing suspended matters and organic nitrogen, and the Committee of the British Association considered the process deserved "further investigation." It appears, however, to have come at present to a standstill.

[3] See *Second Report of the Royal Commission on Metropolitan Sewage Discharge*, page 96.

[4] See *The Engineer*.

[5] This never exceeds one-third of the theoretical or chemical value. Thus the product by Anderson's process at Coventry is estimated *theoretically* at 16s. 9½d. per ton; the *practical* value is only 5s. 6d. to 8s. 4d. See Dr Voelcker's Reports, in the *Report of a Committee on Town Sewage* (1875), p. lx. *et seq.*

occasionally saleable. The profit is never large, and in some instances there has been even a loss. The clear water from all those processes contains ammonia and oxidisable organic matter, as well as phosphoric acid (in most cases), and it would thus appear that a considerable part of the substances which give fertilising power to sewage remains in the effluent water.

The metallic precipitants of various kinds (iron, zinc, manganese) are expensive and the least useful. Blyth's magnesian process was unfavourably reported on by Mr Way.

When the sewer water is cleared by any of these plans, is it fit to be discharged into streams? In the opinion of some authorities, if the precipitate is a good one it may be so, and it appears certain that in many cases it is chemically a tolerably pure water, and it will no longer silt up the bed or cause a nuisance. But it still contains in all cases some organic matter, as well as ammonia, potash, and phosphoric acid.[1] It has, therefore, fertilising powers certainly, and possibly it has also injurious powers. No proof of this has been given, but also no disproof at present, and when we consider how small the agencies of the specific diseases probably are, and how likely it is that they remain suspended, we do not seem to be in a position to expect that the water, after the subsidence of the deposit, will be safe to drink. We must adopt here the plan which is the safest for the community; and the effluent water should therefore be used for irrigation, or be filtered before discharge. The clear fluid is well adapted for market gardens; the plants grown as vegetables for the table are sometimes injured by irrigation with unpurified effluent water.

In arranging any processes for precipitation everything must be as simple as possible; there is no margin for expenditure or complicated arrangements.[2]

The plan recommended for the treatment of the Thames sewage, as given by the Royal Commissioners on Metropolitan Sewage Discharge, was to adopt some method of precipitation at the outfalls at Barking and Crossness, to compress the sludge into cakes, and as a temporary measure let the effluent pass into the Thames. This would get rid of the solids, undoubtedly the greatest source of nuisance. The cakes might be burnt, laid on low-lying land, or taken out to sea and sunk there. Ultimately the effluent ought to be pumped up to appropriate land, and purified by intermittent downward filtration, or by irrigation, if that should prove feasible.

Sewage Cement.

Instead of using the dried deposit as manure, General Scott proposed to make cement, and for this purpose added lime and clay to the sewer water. The deposit contains so much combustible matter that it requires less coal to burn it than would otherwise be the case. General Scott also proposed to use the burnt material as manure to *lime* the land in some cases.

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[1] Many analyses are given in the *First* and *Second Reports of the Rivers Pollution Commissioners*, from which it appears that on an average the chemical processes remove 89·8 per cent. of the suspended matters, but only 36·6 per cent. of the organic nitrogen dissolved in the liquid. Mr Crookes' analyses show that the A B C process, when well carried out, removes all the phosphoric acid. Voelcker's analysis of the effluent water treated by the acid phosphate of aluminum shows that it contains more ammonia than the original sewer water. less organic nitrogen by one-half, and less phosphoric acid; it is pure enough to be discharged into streams.

[2] On the subject of precipitation processes much information will be found in the *Second Report of the Roy. Com. on Metr. Sewage Discharge, op. cit.*

5. *Filtration through Earth, Charcoal, &c.*

By filtration through earth is meant the bringing of sewer water upon a comparatively small area of porous soil, which is broken up and comminuted above, and is deeply underdrained, so that the sewer water may pass through the soil and issue by the drains. Mr Dyke, in explaining the system employed at Merthyr-Tydvil [1] by Mr Bailey-Denton, lays down the following conditions :—There should be—1*st*, a porous soil ; 2*nd*, an effluent drain, not less that 6 feet from the surface ; 3*rd*, proper fall of land to allow the sewage to spread over the whole land ; and, 4*th*, division of filtering area into four parts, each part to receive sewage for six hours, and to have an interval of eighteen hours. He considers that an acre of land would take 100,000 gallons per day, equal to the sewage of 3300 people. At Merthyr-Tydvil 20 acres of land were divided into beds, which sloped towards the effluent drain by a fall of 1 in 150. The surface was ploughed in ridges, on which vegetables were sown ; the sewage (strained) passed from a carrier along the raised margin of each bed into the furrows. The effluent water was stated to be pure enough to be used for drink. Since 1872 these filter-beds, as well as 230 acres of other portions of the land, have been used as ordinary irrigation ground. The effluent water remains bright and pure.[2] Another case of marked success with intermittent filtration is that of Kendal. The best soil for filtration appears to be a loose marl, containing hydrated iron oxide and alumina, but sand and even chalk produce excellent results. But in order that filtration shall be successful it is necessary that the amount of filtering material shall be large ; it must not be less than 1 cubic yard for 8 gallons of sewage in twenty-four hours,[3] and in the case of some soils must be more. If the drains are 6 feet below the surface, then an acre will contain 9680 cubic yards of filtering material, and at 8 gallons per yard an acre would suffice for 77,440 gallons, or the sewage of 2870 people at 30 gallons a head. These views are, however, subject to some modification, since it has been more recently shown that all the oxidation is carried out in the first two, or at the outside, three feet of depth. It would, therefore, seem as if we could greatly increase the amount of sewage in proportion to the soil. Beds 3 feet in depth would probably be found sufficient. Crops may be grown on the land, and indeed it is desirable that they should be.

When the filters are too small they fail to do much good ; and Letheby has given analyses which prove that small filters may be nearly useless. It appears undesirable to use charcoal filters on this account, and all filtration through charcoal has been a failure. *Spongy iron* has been lately very strongly recommended.

Filtration may be downwards or upwards, but the former kind is much more efficacious. Upward filtration may be said to be now abandoned.

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[1] *On the Downward Intermittent Filtration of Sewage at Merthyr-Tydvil*, by T. J. Dyke, F.R.C.S. Eng.

[2] *Report on Town Sewage.*

[3] The Rivers Pollution Commissioners give a smaller amount, viz., 5½ gallons per cubic yard ; but some of their experiments seem to show that we must increase the amount. For example, the soil at Beddington was found by them to have a remarkable power of nitrification up to the extent of 7·6 gallons per cubic yard in twenty-four hours. But when this rate was doubled nitrification ceased, and the soil became clogged. The best soil experimented on (Dursley soil), containing 43 of silica and 18 of oxide of iron, purified 9·9 gallons in twenty-four hours per cubic yard. But as few soils would be so good, the limit of 8 gallons is selected in the text.

Condition of the Effluent Water.—When 5·6 gallons of sewage were filtered in twenty-four hours through a cubic yard of earth, it was found by the Rivers Pollution Commissioners that the organic carbon was reduced from 4·386 parts to 0·734, and the organic nitrogen from 2·484 parts to 0·108 parts in 100,000. The whole of the sediment was removed. Nitrates and nitrites, which did not exist before filtration, were found afterwards, showing oxidation.

6. *Irrigation.*[1]

By irrigation is meant the passage of sewer water over and through the soil, with the view of bringing it as speedily as possible under the influence of growing plants. For this purpose it is desirable that the sewer water should be brought to the land in as fresh a state as possible. In some cases, as at Carlisle, carbolic acid in small quantities has been added to the sewage in its flow for the purpose of preventing decomposition, and the plan appears to be effectual. The sewer water is usually warmer than the air at all times, and will often cause growth, even in winter.

The effect on growing plants, but especially on Italian rye-grass, is very great; immense crops are obtained, although occasionally the grass is rank and rather watery. For cereals and roots it is also well adapted at certain periods of growth, as well as for market vegetables when the viscid parts are separated. When the sewer water permeates through the soil there occur—1*st*, a mechanical arrest of suspended matters; 2*nd*, an oxidation producing nitrification, both of which results depend on the porosity and physical attraction of the soil; and, 3*rd*, chemical interchanges. The last action is important in agriculture, and has been examined by Bischof, Liebig, Way,[2] Henneberg, Warrington,[3] and others. Hydrated ferric oxide and alumina absorb phosphoric acid from its salts, and a highly basic compound of the acid and metallic oxide is formed. They act more powerfully than the silicates in this way. The hydrated double silicates absorb bases. Silicates of aluminum and calcium absorb ammonia and potassium from all the salts of those bases, and a new hydrated double silicate is formed, in which calcium is more or less perfectly replaced by potassium or ammonium. Humus also forms insoluble compounds with these bases. Absorption of potash or ammonia is usually attended with separation of lime, which then takes carbonic acid.

The soil must be properly prepared for sewage irrigation; either a gentle slope, or a ridge with a gentle slope on each side of about 30 feet wide,[4] with a conduit at the summit, or flat basins surrounded by ridges, are the usual plans. The sewer water is allowed to trickle down the slope at the rate of about 8 feet per hour, or is let at once into the flat basin. The water passes through the soil, and should be carried off by drains from 5 to 6 feet deep, and thence into the nearest water-course.

The sewer water should reach the ground in as fresh a state as possible;

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[1] On the application of sewage to land many works have been published. Dr Corfield's work on the *Treatment and Utilisation of Sewage*, 2nd edition, and the *Report of the Committee of the British Association*, 1872, give the best summary of the subject up to the date of publication. Also the *Report of the Committee on Town Sewage*, 1876. A third edition of Dr Corfield's work, in collaboration with Dr Louis Parkes, has since appeared (1887).

[2] *Journal of Royal Agricultural Society*, vol. xi.

[3] *Chemical News*, May 1870. Warrington's paper gives a good resumé of the subject, with many original experiments, and can be consulted for full details.

[4] This was the arrangement of Mr Hope's farm at Romford.

it is usually run through coarse strainers to arrest any large substances which find their way into the sewers, and to keep back the grosser parts which form a scum over the land; it is then received into tanks, whence it is carried to the land by gravitation, or is pumped up. The "carriers" of the sewer water are either simple trenches in the ground, or brick culverts, or concreted channels, and by means of simple dams and gates the water is directed into one or other channel as may be required. Everything is now made as simple and inexpensive as possible—underground channels and jets, hydrants, hose and jets, are too expensive, and overweight the plan with unnecessary outlay.

The amount of land required is, on an average, 1 acre to 100 persons; this is equal to a square of 70 yards to the side, and will take 2000 gallons in twenty-four hours. Later experience seems to show that with proper management less land is required. Dr A. Carpenter, from experience at Croydon, believes that an acre might suffice for 300 persons and even more.

The sewer water is applied intermittently when the plants are growing; but in winter it is sometimes used constantly, so as to store up nourishment in the soil for the plant-growth in the spring.[1]

The amount of sewer water which can be applied will vary with the kind of ground, the amount of rain, and the season of the year. In the year ending 1871, it appears that, on the Lodge farm at Barking, 622,324 tons of sewage were applied to 163 acres (nearly), or about 3800 tons per acre. In the sixteen months ending December 1872, the average quantity was 3342 tons per acre annually. On the most porous part of the farm as much as 960 tons have been applied in twelve hours.[2]

Condition of the Effluent Water after Irrigation.

When the sewer water passes over and not through the soil, it is often impure, and even suspended matters of comparatively large size (such as epithelium) have been found in the water of the stream into which it flows. It requires, therefore, that care shall be taken in every sewage farm that the water shall not escape too soon. Dr Letheby,[3] whose authority on such a question no one can doubt, rated the cleansing power of soil much lower than the Rivers Pollution Commissioners or the Committee of the British Association, and his analyses make it at any rate quite certain that the proper purification of the sewer water demands very careful preparation of the ground in the first instance, and constant care afterwards. But the chemical evidence of the good effect of irrigation is too strong to admit a

[1] See an interesting paper on the "Utilisation of the Sewage of Paris," by Sandford Moore, B.A., Assist.-Surgeon, 4th Dragoon Guards (now Brigade Surgeon, retired) (*Medical Times and Gazette*, June 1870. In the summer "arrosage" is practised: the land is ploughed in furrows and ridges, and the water is allowed to flow into the furrows, and not allowed to wet the vegetables which are planted on the ridges. In winter "colmatage" is had recourse to; the ridges are levelled, and the entire surface is submerged under sewage water. The sewers of Paris receive only a small part of the solid excreta (though most of the urine), but the fluid is highly fertilising. Precipitation with alum was also formerly had recourse to in Paris, but has now been abandoned.

For detailed information, see the Report of the Prefecture of the Seine, *Sur l'Assainissement de la Seine*. An abstract is given in the *Annales des Ponts et Chaussées*, and is translated by R. Manning, M.I.C.E. (E. and F. N. Spon), 1876. Similar works are in process at Berlin, and are described in the same paper. At Brussels the Senne, during its passage through the city, is no longer used as the main sewer, and although the sewage is still poured into it at a lower point, it will ultimately be disposed of by irrigation.

[2] Mr Morgan's Report, quoted in *Food, Air, and Water*, Dec. 1871.

[3] *The Sewage Question*, 1872, pp. 3–27.

doubt to exist, as may be seen from the table given by the Rivers Pollution Commissioners.[1]

The results are much better than those of any chemical precipitant, although they are not quite so good as the downward filtration plan.[2]

Do Sewage Irrigation Farms affect the Public Health or Public Comfort?

That sewage farms, if too near to houses and if not carefully conducted, may give off disagreeable effluvia is certain; but it is also clear that in some farms this is very trifling, and that when the sewer water gets on the land it soon ceases. It is denied by some persons that more nuisance is excited than by any other mode of using manure. As regards health, it has been alleged these farms may—1*st*, give off effluvia which may produce *enteric fever*, or *dysentery*, or some allied affection; or, 2*nd*, aid in the spread of *entozoic* diseases; or, 3*rd*, make ground swampy and *marshy*, and may also poison wells, and thus affect health.

The evidence of Edinburgh, Croydon,[3] Aldershot, Rugby, Worthing, Romford, the Sussex Lunatic Asylum,[4] is very strong against any influence in the production of enteric fever by sewage farms' effluvia. On the other hand, Dr Clouston's record of the outbreak of dysentery in the Cumberland Asylum is counter-evidence of weight, and so is one of the cases noted by Letheby,[5] of enteric fever outbreak at Copley, when a meadow was irrigated with the brook water containing the sewage of Halifax.

[1] The standard of purity which effluent water should have has not yet been fixed. That proposed by the Rivers Pollution Commissioners, which is based on the method of analysis proposed by Dr Frankland, and which is not yet universally admitted, was as follows:—

Standard of Rivers Pollution Commissioners. Maximum of Impurity permissible in 100,000 *parts by weight of the liquid.*

Dry mineral matter in suspension.	Dry organic matter in suspension.	Colour.	In Solution.					
			Organic carbon.	Organic nitrogen.	Any metal except Calcium, Magnesium, Potassium, or Sodium.	Arsenic.	Chlorine.	Sulphur as SH_2, or sulphate.
3	1	Shown in a stratum of 1 inch in a white plate.	2	0·3	2	0·05	1	1

A certain degree of acidity or alkalinity is also ordered not to be surpassed. In the discussions on the Public Health Bill in the House of Commons this standard, which had been embodied in the Bill, was struck out, and the standard is left to be hereafter determined. (No standard is given in the *Rivers Pollution Act* of 1876.) The objection to the plan is not merely the doubt about the substances represented by organic carbon or nitrogen, but also because the standard does not take into consideration the volume of water into which the foul water flows. The Thames Conservancy Commissioners adopt a standard for effluent sewage as follows:—

	Must not exceed in 70,000 parts.	In 100,000.
Suspended matters,	3 parts.	4·3
Total solids,	70 ,,	100·0
Organic carbon,	2 ,,	3·0
,, nitrogen,	0·75 ,,	1·1

[2] On the disposal of sewage a large amount of information will be found in the First and Second Report of the *Royal Commission on Metropolitan Sewage Discharge*, 1884–5; see also Corfield's work, *op. cit.*, 3rd ed., 1887.

[3] Carpenter, various papers and essays on this subject drawn from the experience of Croydon Sewage Farm.

[4] Dr J. W. Williams, *Brit. Med. Journal*, 11th May 1872.

[5] *The Sewage Question*, p. 190.

The negative evidence is, however, so strong as to justify the view that the effluvia from a well-managed sewage farm do not produce enteric fever or dysentery, or any affection of the kind. In a case at Eton, in which some cases of enteric fever were attributed to the effluvia, Dr Buchanan discovered that the sewer water had been drunk; this was more likely to have been the cause.

With regard to the second point, the spread of entozoic diseases by the carriage of the sewer water to the land was at one time thought probable, though, as solid excreta from towns have been for some years largely employed as manure, it is doubtful whether the liquid plans would be more dangerous. The special entozoic diseases which it is feared might thus arise are *Tapeworms*, *Round worms*, *Trichina*, *Bilharzia*, and *Distoma hepaticum* in sheep. Cobbold's latest observations showed that the embryos of *Bilharzia* die so rapidly that, even if it were introduced into England, there would be little danger. The *Trichina* disease is only known at present to be produced in men by the worms in the flesh of pigs which is eaten, and it is at least doubtful whether pigs receive them from the land. There remain, then, only *Tapeworms* and *Round worms* for men and *Distoma hepaticum* for sheep to be dreaded. But, with regard to these, the evidence at present is entirely negative, and, until positive evidence is produced, this argument against sewage irrigation may be considered to be unsupported.

The third criticism appears to be true. The land may become swampy, and the adjacent wells poisoned, and disease (ague[1] and perhaps diarrhœa and dysentery) be thus produced. But this is owing to mismanagement, and when a sewage farm is properly arranged it is not damp and the wells do not suffer.

Objections to Sewers.

The main objections are as follows:—

1. *That, as underground channels connecting houses, they allow transference of effluvia from place to place.*—The objection is based on good evidence, but it must be said in reply that, if proper traps are put down, and if air disconnection, in addition, is made between the outside drains and the house pipe, such transference is impossible. The objection is really against an error of construction, and not against the plan as properly carried out. Besides, the objection is equally good against any kind of sewer, and yet such underground conduits are indispensable.

2. *That the pipes break and contaminate the ground.*— This is a great evil, and it requires care to avoid it. But such strong pipes are now made that, if builders would be more careful to make a good bed and to connect the joints firmly, there would be little danger of leakage, as far as the pipe drains are concerned, and not much damage of the main brick sewers. All pipes, however, ought to be actually and carefully tested after being laid and before being covered in, otherwise it is impossible to ensure their being water-tight, even when everything is sound to all appearance.

3. *That the water supply is constantly in danger of contamination.*—This also is true, and as long as overflow pipes from cisterns are carried into sewers, and builders will not take care to make a complete separation between water pipes and refuse pipes, there is a source of danger. But this is again clearly an error in constructive detail, and is no argument against a proper arrangement.

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[1] There is no ague or any other disease traceable to the sewage irrigation at Craigentinny, near Edinburgh.

On the Influence the Construction of Sewers has had on the Death Rate of Towns.

Reference has already been made to the possibility of sewers being the channels by which enteric fever and cholera have been propagated from house to house, and from which emanations, causing diarrhœa and other complaints, may arise. Admitting the occasional occurrence of such cases, it remains to be seen whether the sanitary advantages of sewers may not greatly counterbalance their defects. The difficulty of proving this point statistically consists in the number of other conditions affecting the health of a town in addition to those of sewerage. Dr Buchanan[1] has, however, given some valuable evidence on this point, which has been well commented on by Sir J. Simon. He inquired into the total death rate from all causes, and the death rate from some particular diseases, in twenty-five towns before and after sanitary improvements, which consisted principally of better water supply, sewerage, and town conservancy. The general result is to show that these sanitary improvements have resulted in a lowering of the death rate in nineteen out of twenty-five towns, the average reduction in these nineteen cases being 10·5 per cent. The reduction of enteric fever was extremely marked, and occurred in twenty-one towns out of twenty-four, the average reduction being 45·4 per cent. in the deaths from enteric fever. In three cases there was an augmentation of enteric fever, but this was manifestly owing to imperfection in the sewerage arrangements; and these cases afford excellent instances of the unfavourable part badly-arranged sewers may play in this direction.[2] Soyka[3] has given some interesting statistics of German towns with regard to this point. In Hamburg the enteric deaths per 1000 total deaths has fallen from 48·5 to 10·5; in Dantzig from 26·6 to 2·3. In Frankfort the enteric deaths per 10,000 living have fallen from 9 to 2; in Munich from 24·2 to 8·9.

Diarrhœa has also been reduced, but not to such an extent; and in some towns it has increased while enteric fever has simultaneously diminished.[4] But the term diarrhœa is so loosely used in the returns as to make any deduction uncertain. Cholera epidemics Dr Buchanan considers to have been rendered "practically harmless." The immense significance of this statement will be at once appreciated. Whether the result is owing solely to the sewerage or to the improved water supply, which is generally obtained at the same time, is not certain. Phthisis, which Dr Buchanan and Dr Bowditch[5] find to be so much influenced by dampness of soil, does not appear to have been affected by the removal of excreta *per se*,—at least towns such as Alnwick and Brynmawr, which are thoroughly drained, show no lowering in the phthisical mortality. Nor could Dr Buchanan trace any effect on the other diseases of the lungs.

As far as can be seen, the effect of good sewerage has therefore been to reduce the general death rate, especially by the reduction of deaths from enteric fever and from cholera (and in some towns from diarrhœa), but partly, in all probability, by general improvement of the health. The action has been, in fact, very much in the direction we might have anticipated.

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[1] *Ninth Report of the Medical Officer to the Privy Council*, p. 12 *et seq.* and p. 40.

[2] See the case of Worthing (p. 45, *Ninth Report*, &c., *op. cit.*), for a striking instance of the spread of enteric fever through sewers.

[3] *Deutsche Viertelj. für Öff. Ges.*, Band xiv. Heft 1, 1882, p. 33.

[4] Virchow has called attention to the lessening of enteric fever.

[5] *Ninth* and *Tenth Reports of the Medical Officers to the Privy Council.* See especially Dr Buchanan's Report in the last-named work, p. 57.

It may be observed that this inquiry by Dr Buchanan does not deal with the question as between sewers and efficient dry methods of removing excreta (on which point we possess at present no evidence), but between sewerage and the old system of cesspools.

Modifications of the Wet Method of Removing Excreta.

The Separate System.

By this term is meant the arrangement which carries the rain-water in separate channels into the most convenient water-course.[1] Mr Ward's celebrated phrase, "the rain to the river, the sewage to the soil," is the principle of this plan. Its advantages are that the sewers can be smaller; that the amount of sewer water to be dealt with at the outflow is much less in quantity, more regular in flow, and richer in fertilising ingredients, and is, therefore, more easily and cheaply disposed of. The grit and débris of the roads also are not carried into the sewers; and the storm waters never flood the houses in the low parts of the town.

The disadvantages are, that separate channels and pipes have to be provided for the rain; that the rain from all large cities carries from roofs and from streets much organic débris which pollutes streams, and that the scouring effect of the rain on sewers is lost, though this last is a very questionable objection.

The adoption of one or other system will probably depend on local conditions. If a town in Europe lies low, and it is expensive to lift sewage; if land cannot be obtained; or if the natural contour of the ground is very favourable for the flow of rain in one direction, while it is convenient to carry the sewage in another, the separate system would be the best. So also in the tropics, with a heavy rainfall and a long dry season, the providing of sewers large enough to carry off the rain would be too expensive for all except the richest cities, and the disposal of the storm water would be difficult.

In all cases in which rain enters the sewers, some plan ought to be adopted for storm waters.[2] If irrigation is the plan carried out, the sewer water becomes so dilute and so large in quantity in storms, that the application to land is usually suspended, and the sewer water is allowed to pass at once into streams.

In this way the evil which irrigation is intended to prevent is produced, though, doubtless, the sewer water is highly dilute. In London the storm waters mingled with sewage are allowed to flow into the Thames, special openings being provided.

The Interception System.

In many of the continental cities the fluid and solid excreta fall into a receptacle with perforated sides or bottom, so that the fluid part drains away and the solid is retained, and is removed from time to time. Such a plan may keep the sewers free from deposit, but has the great disadvantage of retaining large collections of excreta close to and in many cases immediately under or in the cellars of houses, and no ventilation can entirely remove all effluvia.

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[1] On this subject the works of Mr Menzies, who first described this plan, and of Colonel Ewart, R.E. (*Report on the Drainage of Oxford, Eton, Windsor, and Abingdon*, 1868), will be found very useful.

[2] Plans for this purpose are figured and described in the works on *Sanitary Engineering*, by Baldwin Latham and Bailey-Denton.

Dry Methods.[1]

The use of sewers and removal by water are in many cases impracticable. A fall cannot be obtained; or there is insufficient water; or the severity of the climate freezes the water for months in the year, and removal by its means cannot be attempted. Then either the excreta will accumulate about houses, or must be removed in substance daily or periodically. Even when water is abundant, and sewers can be made, many agriculturists are in favour of the dry system, as giving a more valuable fertilising product; and various plans are in use.

It is not necessary to consider here the employment of cesspools, dead-wells, &c., as such plans must be considered quite unsanitary, and should be invariably discontinued. If excreta are ever allowed to accumulate, it should be in properly prepared receptacles, and after admixture with deodorants.

Removal without Admixture.

In some cases the solid and liquid excreta pass into boxes or tanks, which are emptied daily, or from time to time, and the sewage is at once applied to land without further treatment. In Glasgow the excreta from one part of the town, containing 80,000 people, are now removed every day without admixture, except with the garbage from the houses, and are sent long distances at a profit.[2] If the removal can be made daily, the plan is a good one; the manure should not be applied in the immediate neighbourhood of dwellings, and the Barrack Commissioners have ordered that it shall not be put on land nearer barracks than 500 yards.

In some towns in the north of England (Salford, Halifax, Nottingham) the receptacles are lined with some absorbent material (refuse of cloth manufactures), and at Aldershot with stable litter, intended to absorb the urine (Goux system); in other cases the urine is carried off by a pipe into a drain; the intention being, in both cases, to make the fæcal matter drier, and to delay decomposition.

In others, the soil, being removed daily or at short intervals, is taken to a manufactory, and there subjected to manipulations which convert it into a manure.

Under the term "Poudrette," manufactories of this kind have been long carried on in France, though they are said not to be very profitable.[3] At present, however, a portion of the nitrogen of the urea is converted into ammonia, and is united with sulphuric acid, and comes into the market as sulphate. In England, also, there have been several manufactories.

There have been great discussions as to the salubrity of the French poudrette manufactories, and the evidence is that they are not injurious to the workmen or to the neighbourhood, although often disagreeable. But the poudrette can take on a kind of fermentation which renders it

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[1] On the dry methods of removal a very good paper has been published by Dr Buchanan and Mr Radcliffe (*Twelfth Report of the Medical Officer to the Privy Council*, 1870, pp. 80 and 111); also another by Mr Netten Radcliffe (*Report on certain Means of preventing Excrement Nuisances in Towns and Villages*, New Series, No. 2, 1874).

[2] At Carlsruhe, Mannheim, Rastadt, and Bruchsal the excreta are removed in boxes holding about 116 cubic feet (Prussian) every evening. From an experience of eighteen years (1851–1868), the excreta of 6351 men (mean strength) returned 7628 florins per annum, or about 1s. 11d. English money per head. In Bruchsal it was 1s. 1d. and in Mannheim 2s. 6d. per head. This rich manure has converted the sandy wastes into fertile corn-fields.

[3] Nearly all the solid excreta of Paris are dealt with in the same way, at the great depôt of Clichy-la-Garenne.

dangerous, and Parent-Duchâtelet has recorded two cases of outbreaks of a fatal fever (enteric ?) on board ships loaded with poudrette. In the case of the Eureka Company in England no bad effect was produced on the health of the men.

Admixture with Deodorising and Anti-Putrescent Substances.

Usually, however, some deodorising substance is mixed with the excreta before they are removed from the house, and they are then at once applied to land without further preparation. Mr Moule's advocacy of the use of dried earth has brought into prominent notice the great deodorising powers of this substance, and perhaps no suggestion of late years has had more important consequences. The various substances employed to prevent odour and decomposition are as follows :—

1. *Coal and Wood Ashes.*—This is a common practice in the north of England, and closets are made with hinged flaps or seats, so that the coal ashes may be thrown on the sewage. Sometimes screens are used, so that the large cinders are held back, and can again be used for firing. In some towns there are receptacles (middens) intended both for excreta and ashes; sometimes these are cemented, but they are usually porous, and there may be a pipe leading into a sewer, so as to dry them. The midden system is a bad one; even with every care the vast heaps of putrefying material which accumulate in some of our towns must have a very deleterious influence on the health, and the sooner all middens are abolished the better. The deodorising effect of coal ashes is very slight. The mixture of coal ashes and excreta usually finds a sale, but the profit is much greater if no ashes are mixed with it. Wood ashes are far more powerful as deodorisers, but it is not easy in this country to have a proper supply.

2. *Charcoal.*—There is no better deodoriser than charcoal.[1] Animal charcoal is too expensive, and peat charcoal is cheaper; according to Danchell, 3 ounces of peat charcoal are equal to $1\frac{1}{2}$ ℔ of earth; and this author states that the cost of charcoal for a family of six persons would only be 1s. 6d. per month. A plan has been proposed by Mr Stanford,[2] and is in use at Glasgow, which may obviate the difficulty of price. Mr Stanford proposes to obtain charcoal from sea-weed; the charcoal is cheap, and remarkably useful as a deodoriser. After it has become thoroughly impregnated with fæces and urine, the mixture is recarbonised in a retort, and the carbon can be again used; the distilled products (ammoniacal liquor, containing acetate of lime, tar, gas) are sufficient to pay the cost, and it is said even to give a profit.

The closet used with this carbon is, in principle, similar to Moule's earth closet, with various improvements for more thoroughly mixing the charcoal and sewage.

The advantages claimed by Mr Stanford's process are the complete deodorising effect; the small amount of charcoal required as compared with dry earth (three-fourths less required); the value of the dry manure, or of the distilled products, if the mixture is reburnt; and, in the last case (burning), the complete destruction of all noxious agencies. In using it the mixed charcoal and sewage may be stored for some months without odour in some convenient receptacle outside, but not under the house; and Mr Stanford states that all the house urine can be also allowed to flow into this

[1] At Kreilingen, in Holland, a pail system is in use, where charcoal is employed made from burning town refuse. It appears to yield a product of sufficient value to pay itself.
[2] *Chemical News*, June and October 1869 and February 1872.

receptacle. The reburning of the mixture can be done in a gas retort, or a special retort is built for the purpose; the charcoal left in the retort is returned to the house. The so-called "porous carbon," a substance obtained by roasting Devonshire lignite with clay or iron, may also prove useful.

3. *Earth.*—Since the Rev. Mr Moule pointed out the powerful deodorising properties of dried earth, many different closets have been proposed.

Mr Moule's earth closet consists of a wooden box, with a receptacle below, and a hopper above from which dried earth falls on the sewage when the plug is pulled up. The earth is previously dried, and about $1\frac{1}{4}$ to $1\frac{1}{2}$ ℔ of the dried earth per head daily is the usual allowance. For a single house the earth can be dried over the kitchen fire; but if a village is to be supplied a small shed, fitted with tiles, below which smoke pipes from a small furnace pass, is required. The earth used in the closet is sufficient to deodorise the solid excreta and the portion of the urine passed with them, but the rest of the urine and house water has to be carried off in pipes, and disposed of in some other way. The receptacle is emptied from time to time, and the mixture is stored until it can be applied to land. Its value, however, is not great, as most of the nitrogen disappears in a gaseous form. Indeed, so complete is the disintegration of organic matter that even paper disappears, and the earth after redrying has been used again and again.

The advantages of this plan are obvious; its disadvantages are the necessity of collecting, and drying, and storing the earth, which, for cottagers who have little space, and possibly no means of getting earth, is a serious matter. The supply of dried earth to large towns is almost a matter of impossibility, so large is the amount required.[1] Again, the attention necessary to prevent the house water being thrown in, and to remove the soil at sufficiently short periods, sometimes militates against the success. To obviate these disadvantages, some modifications have been introduced into Moule's closet; one side of the receptacle may be covered with a grating, leading to a pipe, so that all fluids drain away, and the house water can be thrown in. In another plan, as in Taylor's improved closet, the urine is carried away without mixing at all with the solid excreta. Sometimes the urine thus separated is led into another box of earth, and is thus more easily disposed of, if there are no means of taking it entirely away; or it is passed into a tank, and then used as liquid manure. In another modification (Moser's original form), a partition along the front holds some absorbent substance (sawdust, straw), into which the urine passes, and the solids are thus kept dry. This separation of the urine and solids certainly appears to be an improvement. Dr Carpenter, of Croydon, reports well of these closets.[2]

The best kind of earth is clay, marl, and vegetable humus; when dried, the clay is easily powdered. Chalk and pure sand are of little use.

The earth system is coming into great use in India, and is carried out with great attention to detail. In those European stations where water is not procurable, Mr Moule's invention has been a boon of great value, and medical officers have stated that nothing has been done in India of late years which has contributed so much in the health and comfort of the men.

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[1] For workhouses, prisons, barracks in country places, where there is plenty of labour, and no difficulty in obtaining and afterwards disposing of the earth, the plan is most perfect. So also for small villages, if some central authority arranges for the supply of earth and for the removal of the used soil. For a good statement of the advantages of the earth system, see Dr Hawksley's paper in the Report of the *Leamington Congress on the Sewage of Towns.*

[2] Bailey-Denton, *op. cit.*, p. 102.

[3] An account of the Bengal arrangements will be found in the 2nd edition of this work, p. 329, but the plans have been much altered.

The plan of separating the urine from the fæces was strongly advocated by Dr Cornish of Madras, and would no doubt be attended with great advantages in India if there are means of disposal of the urine. The chief difficulty in the European barracks in India is felt during the rainy seasons, when the mixed excreta and earth cannot be kept sufficiently dry.

In the case of natives of India, however, a serious difficulty arises in the use of the earth system, in consequence of the universal use of water for ablution after using the closet. Every native takes with him a small vessel holding 10 to 20 ounces of water, so that a large amount of fluid has to be disposed of. The usual earth closet does not suffice for this. Mr Charles Turner, C.E., of Southampton, contrived a closet suitable for the native family;[1] it is unfortunately too costly, and possibly a simple iron box, with a pipe to carry off the urine and ablution water, would be better suited for the poorer classes.

It appears from the observations of Mr Faweus, at the jail of Alipore, that more earth must be used for vegetable than for animal feeders; the experiment gave 5·1 ℔ avoir. ($2\frac{1}{2}$ seers) of undried earth for the daily evacuation of a vegetable-feeding Hindoo. The urine discharge (2 ℔) required 8·2 ℔ of earth. The earth was efficacious in proportion to the vegetable organic matter or humus. In the experiments in this country the clayey matters (silicates of alumina) have seemed to be chiefly useful. In Indian jails and some cantonments the trench system is used; shallow (1 to $1\frac{1}{2}$ foot deep) trenches are dug in a field, and earth is thrown over the excreta; when the trenches are full the whole is ploughed up, and vegetables are at once planted, trenches being dug elsewhere; after two or three crops this portion of the field may be used again. Great importance is attached to the early and repeated cropping of the ground.[2]

4. *Deodorising Powders.*—Instead of charcoal or earth, M'Dougall's or Calvert's *carbolic acid powders* may be used, and this plan has been largely adopted in some Indian stations. A comparatively small quantity is required, but the smell of carbolic acid and the cost are somewhat against the plan. Dr Bond's preparations of terebene, viz., the terebene powder, eupralum, &c., are very efficacious, and have a pleasant odour.

5. *Sawdust* mixed with *sulphuric* or *carbolic acid.*—The mixture of sulphuric acid and sawdust has been found to have little efficacy; the carbolic acid has the disadvantage of the odour, which adheres to the clothes. Choralum powder is also mixed with sawdust, and is moderately efficacious.

6. In Germany, *Süvern's* deodoriser (a mixture of lime, magnesium chloride, and coal-tar) is much used. The *Müller-Schür* deodoriser is composed of 100 ℔ of lime, 20 ℔ of powdered wood charcoal, 10 ℔ of peat powder or sawdust, and 1 ℔ of carbolic acid containing 60 to 70 per cent. of real acid. After mixing, the mass is put under cover for a night to avoid any chance of self-combustion, and when it is dry it is packed in barrels. *Lueder* and *Leidloff's* powder, consisting of ferric sulphate, ferrous sulphate, calcium sulphate, and a little free sulphuric acid, is also much used. It is moderately successful.

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[1] This was done at the suggestion of Dr Niven, of Bombay. Mr Turner's closet is described and figured in Dr Parkes' Report on Hygiene for 1867, *Army Medical Report* for 1866, published 1868, vol. iii. p. 307.

[2] Two objections have been made to the dry earth system:—1. It is almost impossible to get rid of a certain amount of smell, even with deodorants. 2. The product is not very valuable, according to Dr Gilbert's analysis, not so valuable as good garden mould, even after the earth has been twice used. The chief value is therefore a sanitary one.

Arrangement of Closets on the Dry Plan.

As the excreta after being mixed with the deodoriser are in most cases kept for some days or even weeks close to the house, the same rules as to position and construction of closets should be employed as in the case of water-closets. The closet should never be in the basement, but in the roof, or, better still, in a detached building or semi-detached, and with thorough ventilation between it and the house; there should be a pipe leading at once to the outer air from the closet, and one from the receptacle.

The receptacle itself is usually movable; but if not, it should be most carefully cemented, so that no leakage may occur.

With these precautions no odour will be perceived; but it is still very desirable that the removal of the soil should be as frequent as possible. In country houses there is no difficulty, but in towns the removal can seldom be more frequent than once a week, and often is only once a month.

The forms of the closet itself are numerous. Those applicable to the earth plan have been already noticed. Colonel Synge, R.E., has patented a closet for Mr Sandford's charcoal process (the Alver appliance for dry deodorants). In Germany and the north of Europe, where the dry removal, but without admixture with deodorant powders, is in much use, there are various closets in which the urine and fæces are separated.[1] The "air-closet" of Mehlhouse is said to be a good arrangement for houses. The urine runs into a porcelain funnel fixed on the front wall of the pan, and then into an iron vessel, from which it can readily be removed through a valve; the solids fall into an iron receptacle at the back part of the pan. A discharge tube passes from the back and top part of this receptacle into a chimney. Two openings in the front wall, which can be closed by valves, can be used as inlets for the air. If a hopper with charcoal or dried earth were attached to this closet, it would be almost identical with Taylor's improved closet.[2]

Carbonisation.

In 1869, Mr Hickey,[3] of Darjeeling (Bengal Presidency), proposed to carbonise the sewage in retorts, either with or without previous admixture with charcoal. Almost at the same time Mr Stanford[4] proposed the plan, already referred to, of the addition of sea-weed charcoal, and subsequent distillation.

In India the difficulty of obtaining a remunerative price for the ammoniacal products, and the large cost of the apparatus necessary for working the plan, have been unfavourable to its success. Carbonisation has been tried in this country, and if it could be made to return a profit, there can be no question that it is an excellent plan in a purely sanitary point of view.

In Manchester Fryer's patent method is in operation, and it is also being applied, in whole or in part, at Birmingham and at Leeds. It consists of a Destructor, which reduces to slag all the more bulky town refuse, such as

[1] Roth and Lex (*op. cit.*, p. 454) give a good description of these. See also for some good remarks, Pettenkofer's paper on the "Sewerage of Bâle" (*Zeitsch. für Biologie,* Band iii. p. 273).

[2] Dr Bond has also invented a good form of self-acting closet, which separates the urine and fæces. At Manchester and Salford the cinder-sifting closet of Mr Morrell is in use.

[3] *The Carbonisation or Dry Distillation System of Conservancy,* by W. R. S. Hickey, C.E., with a note on *Dry Sewage,* by F. J. Mouat, M.D., Darjeeling, 1869.

[4] "A Chemist's View of the Sewage Question," *Chemical News,* June to October 1869.

cinders and ashes, broken earthenware and glass, which cannot be dealt with except by being accumulated in a rubbish heap. This slag is ground, mixed with lime, and sold as mortar. The apparatus is so arranged that none of the heat is lost, while the heated products of combustion pass over fresh portions of material and prepare it for combustion. The mass is reduced in bulk to one-third. Other refuse, such as condemned food, vegetable garbage, street sweepings, and the like, are reduced to charcoal in another apparatus called the Carboniser. The carbon thus produced is used for disinfecting purposes, for decolorising the waste water from factories, &c. The excreta proper it is proposed to collect in pails and reduce to small bulk by drying in a closed apparatus, called the Concretor, the ammonia being fixed by the sulphuric acid fumes produced by the other processes. By this means the contents of the pails are reduced to one-twelfth, and a valuable manure obtained, which may be either in the form of poudrette or mixed with a little charcoal. Similar plans of disposing of town refuse are in operation in Glasgow and elsewhere.

The Pneumatic Air Plan [1] (Aspiration Plan).

A Dutch engineer, Captain Liernur, proposed some years since an entirely novel plan. No water or deodorising powders are used; the excreta fall into a straight earthenware pipe, leading to a smaller iron siphon pipe, from which they are extracted periodically by exhaustion of the air. The extracting force which can be used (by an air-pump worked by a steam-engine) is said to be equal to a pressure of 1500 ℔ per square foot, which is sufficient to draw the excreta through the tubes with great rapidity. The plan has been tried on the small scale at Prague, Rotterdam, Amsterdam, Leyden, and Hanau, also at Brünn, Olmutz, and St Petersburg, and the opinions concerning it are very various. It does not render sewers unnecessary; indeed, the system contemplates an arrangement of sewers for slop and other waters.

Shone's Ejector System.—This is an opposite plan to Liernur's, the agent

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[1] *The Sewage Question*, by F. C. Krepp, London, 1867. This book was written for the purpose of bringing the Liernur plan before the public, and some parts of it must be taken with limitation.

Reports in *Deutsche Vierteljahrs. für öffentl. Gesundsheitspfl.*, Band iii. p. 313 (1871). *Ibid.*, Band iii. p. 312.

Report of Kauff and Esser, in *Deutsche Viertelj. für öff. Gesundsheitspfl.*, Band iv. p. 316. These gentlemen were sent from Heidelberg to investigate the plan. Report of Messrs Schröder and Lorent (*Ibid.*, Band iv. p. 486). In this Report is a good technical and financial account.

Ballot (*Medical Times and Gazette*, 15th Feb. 1873) spoke favourably of it, and considered it to have been a decided success in Amsterdam and Leyden. Gori, on the other hand (*Med. Times and Gazette*, 8th March 1873), replied to Ballot, denied that this is the case, and declared that in Amsterdam all with one consent say, "It is impracticable." Ballot adheres, however, to his statement.

I saw the system at work in Leyden in Sept. 1876, when much of its results and details was explained to me by the late Professor Boogaard, and again in Amsterdam in 1879 with Captain Liernur himself. It seemed very effectual, and there was a total absence of odour, although I was present in some of the closets at the moment that the contents were sucked away by the apparatus. In Leyden the material is sold in barrels in the liquid form; but at Dordrecht, where the newest and most complete works are, it is made into poudrette, which is said to pay. In this country Mr Adam Scott did his best to bring it to public notice (see his papers in the *Builder, Sanitary Record, Public Health*, &c.). He considered that it had been shown, by five years' experience in Holland, that the pneumatic system, by removing excrement without any possible pollution of air, soil, or water, had banished enteric fever and diphtheria, as well as cholera and any diseases that are conveyed by the discharge from the intestines. The Committee on Town Sewage (Sir R. Rawlinson and Mr C. S. Reade) spoke most disparagingly of it, more so, indeed, than seemed warranted by all the evidence. On the other hand, the patent for Austria and Hungary was purchased by the Vienna Joint-Stock Agricultural Society, who considered it a success, both hygienically and financially.—[F. de C.]

being compressed air instead of exhaustion. It has been applied at Wrexham, at Eastbourne, at Southampton, and elsewhere. It seems especially useful where the ground is flat and it is difficult to get a fall. It works automatically, and gives very little trouble.

Comparison of the different Methods.

Much controversy has arisen on this point, though it does not appear that the question of the best mode of removing excreta is really a very difficult one. It is simply one which cannot be always answered in the same way.

It will probably be agreed by all that no large town can exist without sewers to carry off the foul house water, some urine and trade products, and that this sewer water must be purified before discharge into streams. The only question is, whether fæcal excreta should also pass into the sewers.

It will also be, no doubt, admitted that no argument ought to be drawn against sewers from imperfection in their construction. The advocate of water removal of solid excreta can fairly claim that his argument presupposes that the sewers are laid with all the precision and precaution of modern science; that the houses are thoroughly secured from reflux of sewer air; that the water-closets or water-troughs are properly used; and that the other conditions of sufficient water supply and power of disposal of the sewer water are also present. If these conditions are fulfilled, what reason is there for keeping out of the sewer water (which must, under any circumstance of urban life, be foul) the solid excreta, which, after all, cannot add very greatly to its impurity, and do add something to its agricultural value?

That it is not the solid excreta alone which cause the difficulty of the disposal of sewer water is seen from the case of Birmingham. That town is sewered; when it contained nearly 400,000 inhabitants, it was in the greatest difficulty how to dispose of its sewer water; yet the solid excreta of only 6 per cent. of the inhabitants passed into the sewers, while the solid excreta of the remainder were received into middens.[1] The problem of disposal was as serious for Birmingham as if all the excreta passed in. This difficulty has now been in the main overcome, by the use of the lime precipitating process and the passing of the sewage on land. An innocuous effluent is obtained, and the sewage of over 600,000 people is dealt with, the excreta of about one-sixth of the population passing into the sewers, the remainder being removed by a pail system.[2]

The great difficulty, in fact, consists not so much in the entrance of the solid excreta into sewers as in the immense quantity of water which has to be disposed of in the case of very large inland towns with water-closets. If water-closets are not used, the amount of water supplied to towns, and the amount of sewer water, are both considerably lessened.

Looking to all the conditions of the problem, it appears impossible for all towns to have the same plan, and the circumstances of each town or village must be considered in determining the best method for the removal of excreta. London is particularly well adapted for water sewerage, on account

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[1] *Report of the Birmingham Sewage Inquiry Committee* (1871), Summary, p. 11. It should, however, be added that two-thirds of the middens drain into the sewers, *i.e.*, allow urine and some diffluent fæcal matter to pass in. In 1875, 128,512 tons of midden refuse were removed and sent to country depots, to be afterwards disposed of to farmers.

[2] See evidence of Mr Alderman Avery, *Second Report of the Royal Commission on Metropolitan Sewage Discharge*, 1884.

of the conformation of the ground north of the Thames, of the number of streams (which have all been converted into sewers), and of the comparative facility of getting rid of its sewer water. The same may be said of Liverpool and many other towns.

In many towns where land is available, the immediate application to land, either by filtration or irrigation, may be evidently indicated by the conditions of the case, while in others precipitation may have to be resorted to before application to land. It does not appear that precipitation should in all cases precede irrigation or filtration, though mechanical arrest of the large suspended matters is necessary. There may be some towns, again, in which the impossibility of getting water or land may necessitate the employment of dry removal; and this is especially the case with small towns and villages, where the expense of good sewers and of a good supply of water is so great as to render it impossible to adopt removal by water. It may, indeed, be said that, in small towns in agricultural districts, the dry removal, if properly carried out, will be the best both for the inhabitants and for the land.

The view here taken that no single system can meet all cases, and that the circumstances of every locality must guide the decision, is not a compromise between opposing plans, but is simply the conclusion which seems forced on us by the facts of the case. It does not invalidate the conclusion already come to, that, where circumstances are favourable for its efficient execution, the water-sewage plan (with or without interception of rainfall) is the best for large communities.

CHAPTER IV.

AIR.

It might be inferred from the physiological evidence of the paramount importance of proper aëration of the blood, that the breathing of air rendered impure from any cause is hurtful, and that the highest degree of health is only possible when to the other conditions is added that of a proper supply of pure air. Experience strengthens this inference. Statistical inquiries on mortality prove beyond a doubt that of the causes of death which are usually in action, impurity of the air is the most important. Individual observations confirm this. No one who has paid any attention to the condition of health, and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences, and sometimes even regulates, the second. The average mortality in this country increases tolerably regularly with density of population. Density of population usually implies poverty and insufficient food, and unhealthy work; but its main concomitant condition is impurity of air from overcrowding, deficiency of cleanliness, and imperfect removal of excreta, and when this condition is removed a very dense and poor population may be perfectly healthy. The same evidence of the effect of pure and impure air on health and mortality is still more strikingly shown by horses; for in that case the question is more simple, on account of the absolute similarity, in different periods or places, of food, water, exercise, and treatment. Formerly, in the French army, the mortality among the horses was enormous. Rossignol[1] states that previous to 1836 the mortality of the French cavalry horses varied from 180 to 197 per 1000 per annum. The enlargement of the stables, and the "increased quantity of the ration of air," reduced the loss in the next ten years to 68 per 1000.[2] In 1862–66 the rate of death was reduced to $28\frac{1}{2}$ per 1000, and officers' horses (the property of the State) to 20. The admissions for lung diseases were, in 1849–52, 105, and in 1862–66, 3·59; for glanders, 1847–52, 23; 1862–66, $7\frac{1}{4}$.[3] In the Italian war of 1859 M. Moulin, the chief veterinary surgeon, kept 10,000 horses many months in barracks open to the external air in place of closed stables. Scarcely any horses were sick, and only one case of glanders occurred.[4]

In the English cavalry (and in English racing stables) the same facts are well known. Wilkinson[5] informs us that the annual mortality of cavalry horses (which was formerly great) is now reduced to 20 per 1000, of which one-half is from accidents and incurable diseases. F. Smith[6] puts it at 15 to 25 per 1000, including destructions. Glanders and farey have almost disappeared, and if a case occurs it is considered evidence of neglect.

The food, exercise, and general treatment being the same, this result has

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1 *Traité d'Hygiène Militaire*, Paris, 1857.

2 Wilkinson, *Journal of the Agricultural Society*, No. 50, p. 91 *et seq.*

3 "Vital Statistics of Cavalry Horses," by T. G. Balfour, M.D., F.R.S., Surgeon-General, *Journal of the Statistical Society*, June 1880.

4 Larrey, *Hygiène des Hôp. Mil.*, 1868, p. 63.

5 *Op. cit.*

6 *Veterinary Hygiene*, 1887.

been obtained by cleanliness, dryness, and the freest ventilation. The ventilation is threefold—ground ventilation, for drying the floors; ceiling ventilation, for discharge of foul air; and supply of air beneath the horses' noses, to dilute at once the products of respiration.

In cow-houses and kennels similar facts are well known; disease and health are in the direct proportion of foul and pure air.

The air may affect health by variations in the amount or condition of its normal constituents, by differences in physical properties, or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action. The inquiry is, in fact, in its infancy; it is difficult, and demands a more searching analysis than has been given, although an important commencement has been made by means of biological tests. When impure air does not produce any very striking disease, its injurious effects may be overlooked. The evidences of injury to health from impure air are found in a larger proportion of ill health—*i.e.*, of days lost from sickness in the year—than under other circumstances; an increase in the severity of many diseases, which, though not caused, are influenced by impure air; and a higher rate of mortality, especially among children, whose delicate frames always give us the best test of the effect of food and air. In many cases accurate statistical inquiries on a large scale can alone prove what may be in reality a serious depreciation of public health.

The quantity of air necessary for perfect health will be considered in the section on VENTILATION. In the present chapter the impurities will be mentioned, and then the diseases attributable to them.

The following is the composition of average air:—

Composition of Atmospheric Air.

Oxygen,	209·6 per 1000 volumes.
Nitrogen,	790·0 ,,
Carbonic acid (or carbon dioxide),	0·4[1] ,,
Watery vapour,	varies with temperature.
Ammonia,	trace.
Organic matter (in vapour or suspended, organised, unorganised, dead, or living),	variable.
Ozone,	variable.
Salts of sodium,	variable.
Other mineral substances,	variable.

The amount of oxygen is 209·8 in pure mountain air, while in the air of towns it may fall to 209·0 or 208·7.[2] The mean amount of ozone is given by Levy at 1·15 milligrammes per 100 cubic metres at Montsouris.[3]

The amount of watery vapour varies in different countries greatly, from about 30 per cent. of saturation to perfect saturation; or, according to temperature, from 1 to 11 or even 12 grains in a cubic foot of air. During the rains in the tropics, that amount is not unfrequently exceeded. The best ratio for health has not been determined, but it has been supposed it should be from 65 to 75 per cent.; in many healthy climates, however, it is much more and in some much less than this.

[1] This, although an average for towns, appears to be too high for country districts. Even in towns the recent experiments of Carnelley, Haldane, and Anderson, in Dundee and Perth, have shown that the amount is often less. See *Phil. Trans. Royal Soc.*, vol. clxxviii. (1887).

[2] A. Smith, *Air and Rain*, pp. 335 *et seq.*

[3] *Annuaire for* 1882.

The amount of carbon dioxide in normal air ranges from 0·2 to 0·5 per thousand (or from 2 to 5 volumes in 10,000); it increases slightly up to 11,000 feet of elevation, then decreases; it is augmented under certain circumstances; as in sea-air by day, though not at night; the difference being between 0·54 to 0·33 per thousand (Levy). During the Arctic Expedition of 1875, Dr E. L. Moss, of the "Alert," found it to range from 0·483 to 0·641 per thousand; mean, 0·552,[1] in N. lat. 82° 27′.

Fodor[2] found the CO_2 at Buda-Pesth, during the years 1877–8–9, very constant in quantity, the mean being 0·3886 per 1000 vols. He gives the limits as 0·200 to 0·600, outside which cases occur very seldom, or depend upon errors; the seasonal range is lowest in winter, an increase in spring, again a diminution in summer, and the highest point is reached in autumn. There is less near the sea-shore and more in the middle of the continent; it appears to increase in snow and frost, but to diminish with rain, thaw, and wind; the north wind brings less CO_2 with it than the south. Fodor attributes the greatest influence on the variation of CO_2 in the atmosphere to its rising from the ground air, the CO_2 being always greater at the ground level than one metre above it. Levy[3] gives the mean CO_2 at the observatory of Montsouris at 0·302 per 1000 vols. in a series of five years' observations. In Dundee MM. Carnelley, Haldane, and Anderson found an average of 0·390 and a range of 0·220 to 0·560,—the mean of day-time being 0·380 and night-time 0·410;—this was in open places; in close places at night the mean was 0·420. In the suburbs the mean was only 0·280, with a range of 0·180 to 0·350; and in the outskirts of Perth a mean of 0·310, with a range of 0·290 to 0·350.

Ammonia and organic matter ought probably to be considered as impurities, although they are hardly ever absent.

SECTION I.

IMPURITIES IN AIR.

A vast number of substances, vapours, gases, or solid particles, continually pass into the atmosphere. Many of these substances can be detected neither by smell nor taste, and are inhaled without any knowledge on the part of those who breathe them. Others are smelt or tasted at first; but in a short time, if the substance remains in the atmosphere, the nerves lose their delicacy; so that, in many cases, no warning, and in other instances slight warning only, is given by the senses of these atmospheric impurities.

As if to compensate for this, a wonderful series of processes goes on in the atmosphere, or on the earth, which keeps the air in a state of purity.

Gases diffuse, and are carried away by winds, and thus become so diluted as to be innocuous; or are decomposed if compound, or are washed down by rain; solid substances lifted into the air by winds, or by ascensional force of evaporation, fall by their own weight; or if organic, are oxidised into simple compounds, such as water, carbon dioxide, nitric acid, and ammonia; or dry and break up into impalpable particles, which are washed down by rain. Diffusion, dilution by winds, oxidation, and the fall of rain,

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[1] Dr B. Ninnis, of the "Discovery," found much higher amounts, but the conditions may not have been quite the same, or some accidental error may have occurred. (See *Report of the Committee on the Outbreak of Scurvy*, 1877.)

[2] *Hygienische Untersuchungen über Luft, Boden u. Wasser*, Erste Abtheilung, *Die Luft*. Braunschweig, 1881.

[3] *Annuaire de Montsouris*, 1882.

are the great purifiers; and, in addition, there is the wonderful laboratory of the vegetable world, which keeps the carbon dioxide of the atmosphere within certain limits. If it were not for these counterbalancing agencies, the atmosphere would soon become too impure for the human race. As it is, it is wonderful how soon the immense impurity, which daily passes into the air, is removed, except when the perverse ingenuity of man opposes some obstacle, or makes too great a demand even upon the purifying powers of Nature.

The air passing into the lungs in the necessary and automatic process of respiration, is drawn successively through the mouth and nose, the fauces, and the air tubes. It may consist, according to circumstances, of matters perfectly gaseous (as in pure air), or of a mixture of gases and solid particles, mineral or organic, which have passed into the atmosphere.

The truly gaseous substances will doubtless enter the passages of the lungs, and will meet there with that wonderful surface, covered with the most delicate tufts of blood-vessels, unshielded even, it is supposed by some, by epithelium, which stand up on the surface of 5,000,000 or 6,000,000 air-cells, and through which the blood flows with great velocity; there they will be absorbed, and if, as has been calculated, the surface of the air-cells is as much as from 10 to 20 square feet (and some have placed these figures much higher), we can well understand the ease and rapidity with which gaseous substances will enter the blood.

The solid particles or molecules entering with the air may lodge in the mouth or nose, or may pass into the lungs, and there decompose, if of destructible nature; or may dissolve or break down if of mineral formation; or may remain as sources of irritation until dislodged; or perhaps become covered over with epithelium like the particles of carbon in the miner's lung, or may pass into the epithelium, and enter the body through the lymphatics.

If such particles lodge in the mouth or nose they may be swallowed, and pass into the alimentary canal, and it is even more probable that this should be the case with all except the lightest and most finely divided substances, than that they should pass into the lungs. Although incapable of present proof, there is some reason to think that some of the specific poisons, which float about in an impure atmosphere, such as those which arise from enteric or cholera evacuations, may produce their first effects, not on the lungs or blood, but on the alimentary mucous membrane, with which they are brought into contact when swallowed.

SUB-SECTION I.—SUSPENDED MATTERS.

Nature of Suspended Substances.—An immense number of substances, organic and inorganic, may be suspended in the atmosphere. From the soil the winds lift silica, finely powdered silicate of aluminum, carbonate and phosphate of calcium, and peroxide of iron. Volcanoes throw up fine particles of carbon, sand, and dried mud, which, passing into the higher regions, may be carried over hundreds or even thousands of miles. The eruption of Krakatoa is supposed to have scattered fine dust over the greater part of the globe,[1] and, although the eruption took place in August 1883, Professor Stokes, in his annual address at the close of 1886, suggested that it might not yet have subsided, from the photographic obscuration of the solar corona.

[1] The vibration of the eruption was traced by self-recording barometers 3¼ times round the earth, and seems to have passed through a great polar circle as well as equatorially. See papers by Mr R. H. Scott and Gen. Strachey, *Proc. Roy. Soc.*, vol. xxxvi.

The animal kingdom is represented by the débris of the perished creatures which have lived in the atmosphere, and also it would appear that the ascensional force of evaporation will lift even animals of some magnitude from the surface of marsh water.

From the vegetable world pass up seeds and débris of vegetation; pollen, spores of *fungi*, *mycoderms*, *mucedines*, which may grow in the atmosphere, and innumerable volatile substances, or odours. The germs also of *vibriones*, *bacteria*, and *monads* are largely present, and small eggs of various kinds.

From the sea the wind lifts spray, and the chloride of sodium becoming dried is so diffused through the atmosphere that it is difficult, on spectrum analysis, to find a spectrum without the yellow line of sodium.

The works and habitations of man, however, furnish matters probably of much greater importance in a hygienic point of view.

It is not easy at present to give a complete enumeration of all the substances, but the following are the chief facts, divided under the headings of suspended substances in the external air; in rooms inhabited by healthy persons; in rooms inhabited by sick persons; in workshops and factories.

Suspended Substances in External Air.

1. *Dust and Sand Showers.*—In different parts of Europe there occur from time to time showers of dust and sand. Ehrenberg[1] gives the microscopic examination of seventy showers; in addition to particles of sand and oxide of iron, there were numerous organic forms which are classed by Ehrenberg under the headings of *polygastrica* (194 forms), *phytolithariæ* (145 forms), *polythalamia*, &c. In addition there were portions of plants and fragments of insects. In a dust-storm of February 1872, in Sicily, Silvestri[2] found four species of *diatoms* and living *infusoria*. These sand-storms are sometimes called monsoon showers, but it would appear that any violent storm of a cyclonic character may lift the dust from sandy wastes, as from the African deserts, and transport it great distances.

The suggested meteoric origin of some dust showers is now generally discredited.

There seems no doubt that atmospheric dust may travel to great distances; the air of Berlin has evidently contained organisms derived from the African deserts, and the sails of ships 600 or 800 miles from Africa are often quite red with the sand which lodges on them.

2. Independent of these sand-storms, there are numerous *living creatures* in the atmosphere; some lifted from the ground by winds, others growing in the air. Ehrenberg discovered at least 200 forms—*rhizopods*, *tardigrades*, and *anguillulæ*. These can be dried, and will then retain their vitality for months, and even years.

When the external air is examined either by means of an aëroscope of some kind, or by drawing it through previously heated glass tubes surrounded by a freezing mixture, many of these organisms can be found. The air may also be drawn through tubes lined with nutrient gelatine, or other media, and the number of colonies counted. The following are the most important kinds:—

(*a*) Extremely small round and oval cells, appearing in pairs or adhering together. The cells, described by Lemaire,[3] Trautman,[4] Béchamp, and

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[1] *Uebersicht der, seit* 1847, *fortgesetzten Untersuchungen über das von der Atmosphäre unsichtbar getragene reiche organische Leben.* Berlin, 1871.

[2] *Comptes Rendus*, 1872, p. 991.

[3] *Comptes Rendus de l'Acad.*, Oct. 1867, p. 637.

[4] *Die Zersetzungsgase als Ursache zur Weiterverbreitung der Cholera*, 1869.

others, are exceedingly minute, and it requires a power of 600 to 1000 diameters to see them properly. Trautman states that they grow faster when sulphuretted hydrogen is in the air, and are checked by carbolic acid. Lemaire found them in immense quantities in the air of dirty prison cells, and in the sweat of the prisoners; they will occur, however, in the open air.

These bodies probably correspond to the *micrococci* or *sphærobacteria* of Cohn.

Other *bacteria* are also met with, such as *B. termo* (Microbacteria), *Bacillus* and *vibrio* (Desmobacteria), *Spirillum*, and *Spirochaete* (Spirobacteria). Burdon-Sanderson's observations threw doubt on the existence of *bacteria* in the air as such: D. D. Cunningham also found *bacteria* were rarely present (that is, recognisable) in dry atmospheric dust, but they were occasionally found, as well as a specimen of green *spirillum;* but in the deposit from the moist air of sewers distinct bacteria were frequently observed. The truth probably is that, although they may be rarely met with in full development, this depends on the absence of proper nutriment and favourable conditions for growth, but the existence of their spores (perhaps in some cases the so-called *sphærobacteria*) appears to be clearly proved by the cultivation experiments of Tyndall[1] and Fodor.[2]

The number of *bacteria* also varies with the season (Fodor,[2] Miquel[3]), being greatest in autumn (142) and in summer (105), less in spring (85), and least in winter (49 per metre cube). Part of this variation is due undoubtedly to dryness, for it is observed that in rainy weather they are little to be met with, but after some days of dry weather become plentiful (Nägeli, Fodor, Miquel).

Fodor[4] found at Buda-Pesth, in 1878–79, *bacteria* in 522 out of 646 observations. Drawing the air through a cultivating solution, he found numerous kinds of *bacteria* developed. *Micrococci* or *sphærobacteria* were the most frequent, *spirobacteria* the rarest. *Desmobacteria* were comparatively rare. One form of *microbacterium* he calls *M. agile*, and attributes to it exceptional infective power. *Monads* were rare.

(*b*) *Spores of fungi* are not infrequent; in the open air they occur most commonly in the summer (July and August);[5] they are not in this country more frequent with one wind than another; the largest number found by Maddox in ten hours was 250 spores; on some days not a spore can be found. Maddox leaves undetermined the kind of *fungus* which the spores developed under cultivation; the spores were pale or olive-coloured and oval, probably from some form of smut. Angus Smith found in water through which the air of Manchester was drawn innumerable spores. Mr Dancer has calculated that in a single drop of the water 250,000 fungoid spores as well as mycelium were present, but as the water was not examined for some time there may have been growth. Mycelium of *fungus* seems uncommon in the air, but is sometimes found. The cells of *Protococcus pluvialis* are not uncommon, and perhaps of other *algæ*. Blackley[6] says the amount of spores collected on a slide in four hours amounted to 30,000 or 40,000 per square inch. Dr D. D. Cunningham[7] states that in the air in the suburbs of Calcutta spores

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[1] *Floating Matter in the Air in relation to Putrefaction and Infection*, by John Tyndall, F.R.S. Longman, 1881.
[2] *Op. cit.*
[3] *Annuaire de Montsouris*, 1882, pp. 406 *et seq.;* also separate work, *Organismes vivants de l'atmosphère.* See also Cornil and Babes.
[4] *Op. cit.*
[5] Maddox, *Monthly Journal of the Microscopical Society*, June 1870 and February 1871.
[6] *Experimental Researches on the Causes and Nature of Catarrhus Æstivus*, 1873.
[7] *Ninth Annual Report of the Sanitary Commissioner with the Government of India.*

are constantly present, and usually in considerable numbers. He gives a large number of beautiful drawings.

Fodor[1] found by cultivation that *mucedines* made their appearance 171 times, *sarcinae* 48. *Bacteria* and *fungi* seemed to alternate in seasons and years. Thus in spring *bacteria* were most numerous and *fungi* fewest, whilst the opposite was the case in autumn. Snow and rain lessened the quantity of both.

Carnelley, Haldane, and Anderson found that the average number of organisms in Dundee air was less than one per litre, in the proportion of three *bacteria* to one mould.[2]

(*c*) *Parts of flowers*, especially *pollen*,[3] in the spring and summer are very common,—cuticular scales, vegetable fibres and hairs, seed capsules, globular cells, &c. Near habitations are also found bits of wood often weathered or burnt, bits of charcoal, starch grains, cotton and wool fibres, &c. All these substances appear from Watson's experiments to be more abundant in land than sea air, as might, indeed, be expected.[4]

(*d*) *Animals*, or portions, such as scales from the wings of moths and butterflies; portions of the wings of insects; legs of spiders, bits of spiders' webs, and similar objects, are not uncommon; but sometimes even living animals of some size, apparently rhizopods and amœbiform bodies.

(*e*) *Mineral substances*, fine particles of sand, clay, and chalk are generally met with, even when there is no dust-storm, and are much more common when the ground is dry; rain, indeed, appears not only to prevent these particles from being lifted but also to precipitate those in the air.

In manufacturing districts, or near a railway, there may be even large particles of metals, or pottery clay, or stone in the external air; in the dust collected from a railway carriage near Birmingham, Mr Sidebotham[5] found many large particles of iron capable of attraction by a magnet, and being, in fact, fused particles of iron often covered with spikes and excrescences.

In towns with macadamised roads, dust and remains of horse droppings, finely powdered by the traffic, pass into the air, and as this is more common in dry weather, the sanitary importance of watering and washing the streets of great traffic is manifest.

Mr Tichborne published[6] some analyses of the street dust of Dublin; it contained from 29·7 per cent. of organic matter (at the top of a pillar 134 feet high) to 45·2 per cent. (in the air of a street); the organic matter was chiefly stable manure finely ground; it acted as a ferment, and reduced nitrate of potassium into nitrite; it had, therefore, a strong deoxidising power. The plate (No. V.) drawn by Dr J. D. Macdonald, R.N., F.R.S., shows some of the substances collected from the external air in the garden of St Mary's Hospital, Paddington.[7]

(*f*) It cannot be doubted that various organic substances dried in the ground and finely pulverised, may be lifted into the air by winds, and may be carried to great distances; under the microscope the particles would probably appear formless, and could not be referred to any special class,

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[1] *Op. cit.* [2] *Op. cit.*

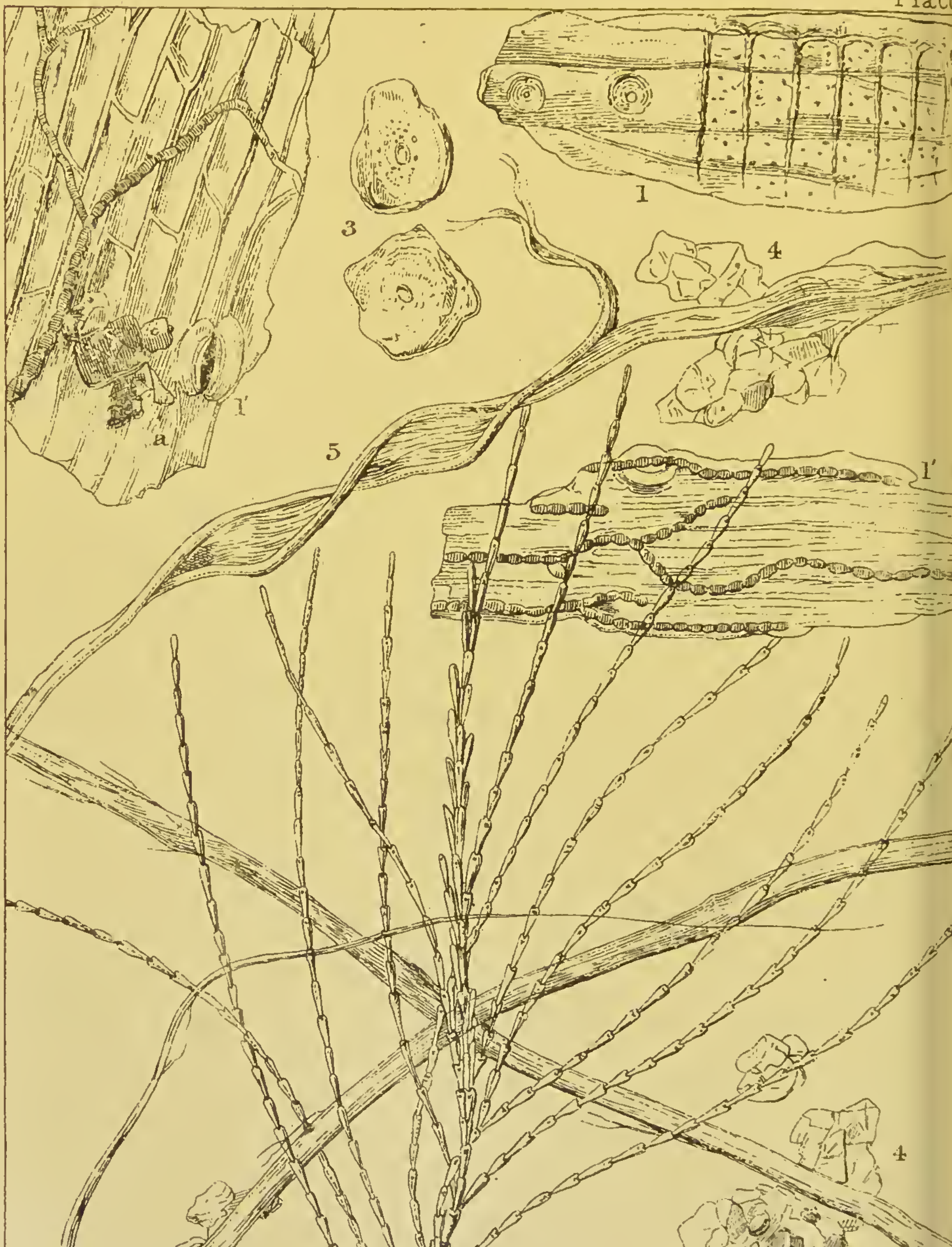
[3] Blackley (*op. cit.*) shows that pollen is in large quantities, sometimes amounting to 7870 grains per square inch of slide. In the upper strata of the air (at 400 to 500 feet) he found much more than in the lower,—on an average 19 times as much. Cunningham (*op. cit.*) also found pollen in large quantity.

[4] *Army Medical Department Report*, vol. xi. p. 529 (1871).

[5] *Chemical News*, October 1871. [6] *Ibid.*, Oct. 1870.

[7] From *Three Reports on the Sanitary Condition of St Mary's Hospital, Paddington*, by Surgeon-Major F. de Chaumont, M.D., 1875-76.

Plate



EXTERNAL AIR.

Description of Plate V.

External Air.

Fig. 1. Fragment of pine-wood.
1′. Epidermis of hay, with fungus attached.
2. Linen fibres. *N.B.* The thick fibres crossing in lower third of plate.
3. Epithelium (nucleated) from the mouth.
4. Do. detached from the skin.
5. Cotton fibre.
6′. Feather, or down.
ā. Charred vegetable particles, and mineral matter.

(*To Binder—To face Plate V.*)

Description of Plate VI.

Accident Ward.

Fig. 1′. Epidermis of hay. 1. Do. with fungus attached.
2. Linen fibre.
2′. Fungus filament. *N.B.* Long narrow filament in upper left of plate.
3. Nucleated epithelium from the mouth.
3*a*. Pus cells.
4. Worn epithelium from the skin.
4*a*. Charred vegetable particles. 4*d*. Fungus spores.
5. Cotton fibre.
6. Woollen fibre.
7. Fragments of insects.
8. Pine pollen.
9. Dried-up palmellaceous frond.
10. Ciliated spore, probably of *Vaucheria*.

(*To Binder—To face Plate VI.*)

ACCIDENT WARD, ST. MARY'S HOSPITAL, LONDON.

but would be included under the term of "dust," or "amorphous matter." In this way it is believed that some diseases may be propagated; cholera, for example, by the particles of dried excreta lifted and carried by the wind, and smallpox and scarlet fever by the disintegrated epidermis or dried discharges.[1]

Some of the various particles of different kinds thus suspended in the air reflect and scatter the rays of light, and produce the appearance of fine motes, which are familiar to every one, as seen in the course of a ray of light passing through a dark room, or when an electric beam is transmitted through a tube. When the air is kept motionless they subside, so that most of them have some weight, though some are so light as to float in rarefied air (Tichborne); when heated, Tyndall has shown that many of them are burnt, and a little bluish mist arising from the combustion can even be perceived; the destructible nature proves, of course, the organic origin of those consumed, but does not show whether they are organised or not. That is a point, however, which can now be determined, to some extent at least, by cultivation experiments.

Suspended Matters in Enclosed Spaces.

1. *Rooms inhabited by Healthy Persons.*—In all inhabited rooms which are not perfectly ventilated, the presence of scaly epithelium, single and tesselated; round cells like nuclei, portions of fibres (cotton, linen, wool), portions of food, bits of human hair, wood, and coal, can be found in addition to the bodies which are present in the external air, though, as pointed out by Watson, mineral matters and vegetable matters are not so plentiful, as the comparative stillness of the air allows them to fall.[2] Carnelley, Haldane, and Anderson show that there is an enormous increase of *bacteria* in crowded and ill-ventilated rooms, whilst the *moulds* do not increase to the same extent. When the *moulds* and *bacteria* in the external air were as 1 to 3, in houses of four rooms and upwards they were as 4 to 85, in two-roomed houses as 22 to 430, and in one-roomed houses as 12 to 580.

In some cases articles of furniture may furnish certain substances; the flock wall-papers, coloured green by arsenical preparations (especially Scheele's green and Schweinfürth green), give off little particles of arsenical dust into the room;[3] and it has been shown by Professor Fleck[4] that the arsenious acid in the Schweinfürth green, when in contact with moist organic substances, and especially paste or size, forms arseniuretted hydrogen,[5] which diffuses in the room, and is no doubt the cause of some of the cases of arsenical poisoning from green papers.

2. *Sick Rooms.*—In addition to being vitiated by respiration, the air of sick-rooms is contaminated by the abundant exhalations from the bodies of

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[1] In the air of the back-yard of a London hospital I found considerable quantities of epithelium; and in the "dirty linen area," where the foul linen was kept in crates till washed, I found not only epithelium, but even pus globules, and also a quantity of fatty crystals, apparently from dressings. There were also *bacteria*, both free and in the zooglœal form.—[F. de C.]

[2] Numerous observations on the air of barracks and military hospitals have been made by medical officers of the army, especially by Drs de Chaumont, Frank, Hewlett (of Bombay), Stanley, Baynes Reed, Venner, Watson, and many others. (See the *Army Medical Department Annual Reports*, from 1860-70).

[3] Halley and many others.

[4] *Zeitsch. für Biologie*, Bd. viii. p. 445 (1872).

[5] Perhaps other substances are also formed, such as cyanide of kakodyle, which is intensely poisonous (Bartlett).

the inmates, and by the effluvia from discharged excretions. The amount of organic matter is known to be large, but it is difficult at present to give a quantitative statement. Moscati, who (in 1818) condensed the watery vapour of a ward at Milan, describes it as being slimy, and as having a marshy smell. The peculiar smell of an hospital is indeed very remarkable, and its similarity in hospitals of different kinds seems to show that the odorous substance has a similar composition in many cases. The reaction of ozone is never given in such an atmosphere.

Devergie found an "immense amount" of organic matter in the air in the vicinity of a patient with hospital gangrene.

The dust of a ward in St Louis, in Paris, examined by Chalvet, was found in one experiment to contain 36 per cent. of organic matter, and in another 46 per cent. When burnt, it gave out an odour of horn. The dust collected in hospitals for diseases of the skin is stated by Gailleton to be full of sporules of *Trichophyton*. They can be found in the air of the ward when condensed by ice.

Much interest was excited in 1849 by the discovery by Drs Brittan and Swayne, of Clifton, of bodies very like *fungi* in the air of a cholera ward; later researches lead to the opinion that this observation was perfectly correct, though the connection between these *fungi* and cholera is still quite uncertain. In 1849, also, Dr Dundas Thomson drew the air of a cholera ward through sulphuric acid: various suspended substances were arrested, —starch, woollen fibres, epithelium, *fungi* or spores of *fungi*, and *vibriones*. Mr Rainy also found in the air of a cholera ward in St Thomas' Hospital the spores and mycelium of *fungi* and *bacteria*. Some of these bodies were found, however, in the open air. In hospitals for skin diseases *Achorion* has been detected in the air where there are patients with *favus*; and Tilbury Fox[1] figured the spores (clustered and in chains) and the mycelium of *Trichophyton* in a ward with a number of children with *Tinea circinata*.

In a ward in Netley Hospital (under Brigade-Surgeon Veale, M.S.), where repeated cases of erysipelas occurred, the air was found to be loaded with *fungi*. The ward being emptied, and the floor, walls, and ceiling being washed with carbolic acid, the disease ceased.

The scaly and small round epithelia found in most rooms are in large quantity in hospital wards; and probably, in cases where there is much expectoration or exposure of pus or puriform fluids to the air, the quantity would be still larger.

In the well-ventilated wards of the Dundee Royal Infirmary Carnelley, Haldane, and Anderson found a very small number of micro-organisms.[2]

Considering that the pleuro-pneumonia of cattle is probably propagated through the pus and epithelium cells of the sputa passing into the air cells of other cattle; that even in man there is evidence of a pneumonic or phthisical disease being contagious,[3] the floating of these cells in the air is worthy of all attention. In the air of a phthisical ward at Netley, Dr Watson not only found pus cells, but bodies which were not found in the external air or in the rooms of healthy persons, and which are very like the cells seen in tuberculous matter. In military granular conjunctivitis (grey granulations), the remarkable effect of ventilation in arresting the spread (Stromeyer) seems to show that we have here a similar case, and that ventilation acts by diluting, oxidising, and drying the cells thrown off

[1] *Lancet*, January 1872. [2] *Op. cit.*
[3] Bryson, *Cases in the Mediterranean Fleet*.

from the conjunctivæ. In smallpox wards, Bakewell found unequivocal evidence of minute scales of smallpox matter in the air. It seems probable that the discovery of suspended matters of this kind will lead to most important results.[1] The possibility of a direct transference from body to body of cells undergoing special chemical or vital changes is thus placed beyond doubt, and the doctrine of contagion receives an additional elucidation. It is now generally admitted that protophytes like *Protococcus pluvialis* may be dried, and yet retain their vitality even for years, and may be blown about in atmospheric currents; and, should contagion be proved to depend upon minute organisms, these might easily be carried about in a similar way, either alone or carried by epithelium or other particles thrown off from the bodies of patients. The success which has sometimes attended the treatment of pleuro-pneumonia in cattle by means of carbolic acid (Crookes), and the apparent advantage of inhaling disinfectants in human phthisis, seem to point to a similar active cause in those maladies; and this appears in some sort confirmed by the observations of Koch on the *bacillus* of phthisis, which is said to have been found in the breath of phthisical patients.

3. *Workshops, Factories, and Mines.*—Grinding of steel and iron, and stones; making metallic and pearl buttons; melting zinc; melting solder; carding and spinning textile fabrics of all kinds; grinding paint; making cement, and in fact almost innumerable trades cause more or less dust, derived from the fabrics and materials, to pass into the air.

Dr Sigerson[2] found a black dust composed of carbon, iron (in the shape of small jagged pieces and also as hollow balls $\frac{1}{2000}$ of an inch in diameter), and ash, in metal shops. In the air of a printing office there was enough antimony to be chemically detected. In the air of stables were equine hairs, epithelium, moth-cells, ovules, and various fungi.

In addition to these suspended matters, which vary with the kind of work, the air of workshops is largely contaminated by respiration and by the combustion of gas.

In mines the suspended matters are made up of the particles of the particular substance which is being worked, or of rock excavated to obtain metals, of sooty matters from lamps and candles, and of substances derived from blasting.

Sub-Section II.—Gaseous Substances.

A great number of gases may pass into the atmosphere either from natural causes or from the works of man.

Compounds of Carbon.—Carbon dioxide (abnormal if exceeding 5 in 10,000 parts), carbon monoxide, carburetted hydrogen or methane, and peculiar substances (gaseous) in sewer air.

Compounds of Sulphur.—Sulphur dioxide, sulphuric acid, hydrogen sulphide, ammonium sulphide, and carbon disulphide.

Compounds of Chlorine.—Hydrochloric acid from alkali works.

Compounds of Nitrogen.—Ammonia and ammonium acetate, sulphide, and carbonate (normal in small amount?), and nitrous and nitric acids.

Compounds of Phosphorus.—Hydrogen phosphide.

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[1] In the accident ward of St Mary's Hospital, Paddington, I found pus cells in the air, near some beds which had a bad reputation for erysipelas. See plate drawn by Dr Macdonald (*Report on St Mary's, op. cit.*).—[F. de C.]

[2] *British Medical Journal*, June 1870, from Memoirs of the Royal Irish Academy, in which publication are some excellent observations by the same writer.

Organic Vapours.—Of the exact composition of the vapours, often fœtid, which arise from various decomposing animal matters, little is known.

Sub-Section III.—Nature of Impurities in certain Special Cases.

Air Vitiated by Respiration.

Carbon Dioxide.—An adult man, in a state of repose, gives off in twenty-four hours from 12 to 16 cubic feet or more, according to weight, of carbon dioxide, the most of it from the lungs, although he also emits an undetermined quantity by the skin. On an average an adult man, of say 12 stone weight, in a state of rest, may be considered to give to the atmosphere every hour not less than ·72 cubic foot of CO_2. Women give off less, about 0·6; and children and old people also give off a smaller amount. The amount given off by women, say 0·6, may be adopted for a mixed community.

The amount of CO_2 in pure air being assumed to be on an average 0·4 per 1000,[1] or four volumes per 10,000, the quantity in the air of the rooms vitiated by respiration varies within wide limits, and many analyses will be found in books. The following table is a part of the numerous experiments on barrack-rooms by Dr de Chaumont on this point, in which the amount of CO_2 in the external air was simultaneously determined. The analyses were made at night, when the men were in the rooms. The cubic space per head was 600 feet in the barracks and from 1200 to 1600 in the hospitals:—

Amount of Carbon Dioxide in 1000 *Volumes of Air* (*de Chaumont*).

	CO_2 in External Air.	CO_2 in Room.		Mean Respiratory Impurity.
		Largest Amount found.	Mean Amount.	
Barracks.				
Gosport New Barracks,	·430	1·846	·645	·215
Anglesey Barracks,	·393	1·971	1·404	1·011
Aldershot,	·440	1·408	·976	·536
Chelsea,	·470	1·175	·718	·248
Tower of London,	·420	1·731	1·338	·898
Fort Elson (Casemate),	·425	1·874	1·209	·784
Fort Brockhurst (Casemate),	·422	1·027	·838	·416
Military and Civil Hospitals.				
Portsmouth Garrison Hospital,	·306	2·057	·976	·670
Portsmouth Civil Infirmary,	·322	1·309	·928	·606
Herbert Hospital,	·424	·730	·472	·048
Hilsea Hospital,	·405	·741	·578	·173
St Mary's, Paddington,	·560	1·534	·847	·287
Military and Civil Prisons.				
Aldershot Military Prison—Cells,	·409	3·484	1·651	1·242
Gosport Military Prison—Cells,	·555	2·344	1·335	·780
Chatham Convict Prison—Cells,	·452	3·097	1·691	1·239
Pentonville Prison—Cells—Jebb's system,	·420 [2]	1·926	·989	·569

[1] The average at the park of Montsouris, at Paris, is only 0·3; see *L'Annuaire;* perhaps 0·35 would be more correct for country air.

[2] Assumed at ·420.

The last column of the table shows the condition of the ventilation as measured by the CO_2; it is very satisfactory in the newer barracks (Gosport and Chelsea), but is much less so in the older barracks and casemates. The Herbert and Hilsea military hospitals show excellent ventilation, while the old-fashioned Portsmouth garrison hospital is in this respect very bad. The prison cells show, in all cases, a very high degree of respiratory impurity, and this must be one of the depressing influences of long cell confinement. Wilson[1] gives some important information on this point. In cells (in Portsmouth Convict Prison) of 614 cubic feet, always occupied, he found the $CO_2 = 0{\cdot}720$ per 1000; the prisoners were healthy and had a good colour. In cells of 210 cubic feet, occupied only at night by prisoners employed outside during the day, he found 1·044 per 1000 of CO_2; the occupants were all pale and anæmic.

The CO_2 of respiration is equally diffused through the air of a room (Lassaigne, Pettenkofer, Roscoe); it is very rapidly got rid of by opening windows, and in this respect differs from the organic matter, and probably from the watery vapour; neither appears to diffuse rapidly or equably through a room.

The amount of CO_2 is often much greater than in the above instances. In a boys' school with 67 boys and 4640 cubic feet (= 69 cubic feet per head) Roscoe found 3·1 parts of CO_2 per 1000. In one-roomed houses in Dundee 3·21 per 1000 was found as a maximum by MM. Carnelley, Haldane, and Anderson;[2] this was 2·63 above the external air. In a schoolroom, naturally ventilated, with an average of 168 cubic feet per head, the mean CO_2 was 1·86 and the maximum 3·78; in another, with the same space but mechanically ventilated, the average was 1·23 and the maximum 1·96.[3] In the Dundee Royal Infirmary (space per head from 1034 to 3182) the CO_2 ranged from 0·41 to 0·78, or a range of respiratory impurity between 0·06 and 0·37.[4] In Leicester, in a room with six persons, and only 51 cubic feet of space per head, and with three gas lights burning, Mr Weaver[5] found the CO_2 to be 5·28 parts per 1000; while in a girls' schoolroom (70 girls and 10,400 cubic feet, or 150 cubic feet per head), Pettenkofer found no less than 7·230 parts per 1000. In many schools, workrooms, and factories the amount of respiratory impurity must be as great as this, and doubtless a constant unfavourable effect is produced on health. Dr Hayne (in H.M. ship "Doris") found the CO_2 to range from 1·03 to 3·21 between decks, the latter quantity being in the ward-room with the scuttles in.[6] In the Arctic Expedition of 1875–76, Dr Moss found as much as 4·82 in the ward-room of the "Alert," "room feeling very close;" and Dr Ninnis found 5·57 in the lower deck of the "Discovery."

Gartner[7] found in the army corvette "Jackson" about 1·0 between decks, as much as 6·42 in the sick-bay, 5·54 in the cells, and no less than 50 in the powder magazine.

In a horse stable at the École Militaire the amount was 7 per 1000. At Hilsea, with a cubic space of 655 cubic feet per horse, the amount was 1·053; and in another stable, with 1000 cubic feet per horse, only 0·593 per 1000

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[1] *Handbook of Hygiene.* [2] *Op. cit.*
[3] *Op. cit.* [4] *Op. cit.*
[5] Mr Weaver gives several good analyses in different public and private rooms in Leicester. *Lancet*, July and August 1872.
[6] *Med. Chir. Trans.*, vol. lvii.
[7] *Deutsche Vierteljahrschrift für öffentliche Gesundheitspflege*, Bd. xiii. p. 369, 1881.

(de Chaumont). Märeker found 8·5 in a stable in Gottingen, and no less than 17·07 in a byre.

Mr Fred Smith (Army Veterinary Department) has shown that the CO_2 determinations in stables are greatly influenced by the amount of ammonia in the air interfering with the reaction, thus indicating a factitious purity of atmosphere.

Moisture.—Organic Matter.—By the skin and lungs pass off from 25 to 40 ounces of water in twenty-four hours, to maintain which in a state of vapour 211 cubic feet of air per hour are necessary on an average. Of course, however, temperature and the hygrometric condition of the air greatly modify this. Organic matter is also given off from the skin and lungs, the amount of which has never been precisely determined. Nor is it possible, at present, to estimate it correctly. This organic matter must be partly suspended, and is made up of small particles of epithelium and fatty matters detached from the skin and mouth, and partly of an organic vapour from the lungs and mouth. The organic matter from the lungs, when drawn through sulphuric acid, darkens it; through permanganate of potash, decolorises it; and through pure water, renders it offensive. Collected from the air by condensing the watery vapour on the sides of a globe containing ice (as by Taddei in the wards of the Santa Maria Novella), it is found to be precipitated by nitrate of silver, to decolorise potassium permanganate, to blacken on platinum, and to yield ammonia. It is therefore nitrogenous and oxidisable. It has a very fœtid smell, and this is retained in a room for so long a time, sometimes for four hours, even when there is free ventilation, as to show that it is oxidised slowly. It is probably in combination with water, for the most hygroscopic substances absorb most of it. It is absorbed most by wool, feathers, damp walls, and moist paper, and least by straw and horse-hair. The colour of the substance influences its absorption in the following order:—black most, then blue, yellow, and white. It is probably not a gas, but is molecular, and floats in clouds through the air, as the odour is evidently not always equally diffused through a room. In a room, the air of which is at first perfectly pure, but is vitiated by respiration, the smell of organic matter is generally perceptible when the CO_2 reaches 0·7 per 1000 volumes, and is very strong when the CO_2 amounts to 1 per 1000.[1] From experiments made at Gravesend, Netley, Aldershot, and Hilsea, by various medical officers,[2] it has been shown that the amount of potassium permanganate destroyed by air drawn through its solution is generally in proportion to the amount of CO_2 of respiration.

When the air of inhabited rooms is drawn through pure water, and the free ammonia got rid off, distillation with alkaline permanganate, in the method of Wanklyn, gives a perceptible quantity of "albuminoid ammonia." In a bed-room at 9 P.M., A. Smith[3] found 0·1901 milligrammes in 1 cubic metre of air; at 7 A.M. there were 0·3346 milligrammes in each cubic metre.

The average of eight observations in the external air (at Portsmouth) gave 0·0935 of free NH_3, and 0·0886 of albuminoid NH_3 in milligrammes per cubic metre. In the Portsmouth General Hospital the free NH_3 was as high as 0·855, and the albuminoid 1·307.[4]

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[1] On this point see table at page 193. [2] See note, p. 137.

[3] *Air and Rain*, p. 436.—If expressed as grammes per million cubic metres, the amount is 190·114 and 334·601; in grains, in 1 million cubic feet, the numbers are 83·074 and 146·210.

[4] Moss, *Lancet*, Nov. 8, 1872.

The following is from Dr de Chaumont's Reports on the Ventilation Experiments at St Mary's Hospital, Paddington :—

Milligrammes per Cubic Metre.

	Free NH_3.	Albuminoid NH_3.	Organic oxygen.	Total oxygen for oxidisable matter.	Remarks.
External air, July 1875, .	0·3574	0·5280	...	1·4300	Air damp and still, wind S.W., slight.
Wards, .	0·6680	0·4710	...	1·4900	
Do. . .	0·6669	0·6770	...	1·5100	
Do. . .	0·3519	0·6915	...	1·3600	
External air, August 1876, .	0·0163	0·5206	0·4444	0·5714	Air dry and warm, wind S.E. by E., fresh.
Wards, .	0·0497	0·4622	0·3747	0·5621	
Do. . .	nil	0·2824	0·2571	0·5142	
Do. . .	0·0310	0·3576	0·3101	0·3567	
Do. . .	0·0127	0·5259	0·2225	0·4451	
Do. . .	0·0100	0·3684	0·4420	0·6315	

It is evident that the condition of the external air, with regard to movement and humidity, has a great deal to do with the amount of organic matter. The nitrogen acids are also met with; in one instance, in the above experiments, they reached in a ward 28·484 per metre, of which 0·7392 was nitrous and the rest nitric acid.

The Dundee experiments already cited state the organic matter in vols. of oxygen required to oxidise it per 1,000,000. This is equal to c.c. per cubic metre, each c.c. of oxygen weighing 1·43 of a milligramme. The results are much higher than those in the above table, the mean oxygen for organic matter in the external air in the town being 8·9, and in the suburbs 2·8 vols. per 1,000,000; they would equal 12·7 and 4 milligrammes respectively. In dwellings it was found to increase, but not to the marked extent that was observed in *bacteria*, but the increase was sufficiently proportionate to the CO_2 to support the view that they are generally coincident, although varying much in individual cases. On the other hand, there seems little relation between the CO_2 and the number of micro-organisms.[1]

Air vitiated by Combustion.

The products of firing pass out into the atmosphere at large; those of lighting are for the most part allowed to diffuse in the room.

Coal of average quality gives off in combustion—

1. *Carbon.*—About 1 per cent. of the coal is given off as fine carbon and tarry particles.

2. *Carbon dioxide.*—In Manchester, Angus Smith calculated some years ago that 15,000 tons of carbon dioxide were daily thrown out, and the quantity must now be still larger. In London over 30,000 tons of coal a day are consumed, and this would yield nearly 90,000 tons of carbon dioxide.

3. *Carbon monoxide.*—The amount depends on the perfection of combustion.

4. *Sulphur, sulphur dioxide,* and *sulphuric acid.*—The amount of sulphur in coal varies from $\frac{1}{2}$ to 6 or 7 per cent. In the air of Manchester, A. Smith found 1 grain of sulphuric acid in 2000 and 1076 cubic feet.

[1] *Phil. Trans., loc. cit.* See also "The Determination of Organic Matter in the Air," by Professor Thos. Carnelley, D.Sc., and Wm. Mackie, M.A., University College, Dundee.—*Proc. Royal Society*, vol. xli. p. 238.

5. *Carbon disulphide.*
6. *Ammonium sulphide* or *carbonate.*
7. *Hydrogen sulphide* (sometimes).
8. *Water.*

From some manufactories there pour out much greater quantities of SO_2 (copper works), arsenical fumes, hydrogen sulphide, carbon dioxide, &c.

For complete combustion 1 ℔ of coal demands about 240 cubic feet of air.

Wood produces carbon dioxide and monoxide and water in large quantity, but few compounds of sulphur. 1 ℔ of dried wood demands about 120 cubic feet of air for complete combustion.

Coal-gas, when fairly purified, is composed of—	in 100 parts
Hydrogen,	40 to 45·58
Marsh gas (light carburetted hydrogen or methane),	35 to 40
Carbon monoxide,	3 to 6·6
Olefiant gas (ethylene or ethene),	3 to 4
Acetylene (or ethine),	2 to 3
Hydrogen sulphide,	0·29 to 1
Nitrogen,	2 to 2·5
Carbon dioxide,	3 to 3·75
Sulphur dioxide,	·5 to 1
Ammonia or ammonium sulphide,	(or in the best cannel-
Carbon disulphide,	coal gas only traces).

In some analyses the carbon monoxide has been as high as 11 per cent., and the light carburetted hydrogen 56; in such cases the amount of hydrogen is small. As much as 60 grains of sulphur have been found in 100 cubic feet of gas.[1] The parliamentary maximum is 20 grains in 100 cubic feet. In badly purified gas there may be a great number of substances in small amount, especially hydrocarbons and alcohols, such as propylene, butylene, amylene, benzole, xylol, some of the nitrogenous oily bases, such as pyrrol, picoline, &c.[2]

When the gas is partly burnt, the hydrogen and light and heavy carburetted hydrogens are almost destroyed; nitrogen (67 per cent.), water (16 per cent.), carbon dioxide (7 per cent.), and carbon monoxide (5 to 6 per cent.), with sulphur dioxide and ammonia, being the principal resultants. And these products escape usually into the air of rooms. With perfect combustion there will be little carbon monoxide.

According to the quality of the gas, 1 cubic foot of gas will unite with from 0·9 to 1·64 cubic feet of oxygen, and produces on an average 2 cubic feet of carbon dioxide, and from 0·2 to 0·5 grains of sulphur dioxide. In other words, 1 cubic foot of gas will destroy the entire oxygen of about 8 cubic feet of air. One cubic foot of gas will raise the temperature of 31,290 cubic feet of air 1° Fahr.

Oil.—A lamp with a moderately good wick burns about 154 grains of oil per hour, consumes the oxygen of about 3·2 cubic feet of air, and produces a little more than $\frac{1}{2}$ a cubic foot of carbon dioxide; 1 ℔ of oil demands from 140 to 160 cubic feet of air for complete combustion.

A candle of 6 to the ℔ burns per hour about 170 grains.

The products of the combustion of coal and wood pass into the atmosphere,

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[1] *Chemical News*, March 1865, p. 154.

[2] For a fuller list of these substances, which do not appear very important, see Pappenheim's *Handbuch der San. Pol.*, Band iii. Supp. p. 261.

and usually are at once largely diluted. Diffusion and the ever-moving air rapidly purify the atmosphere from carbon dioxide.

It is not so, however, with the suspended carbon and tarry matters, which are too heavy to drift far or to ascend high. As a rule, the particles of carbon are not found higher than 600 feet; and the way it accumulates in the lower strata of the atmosphere can be seen by looking at any lofty building in London. The air of London is so loaded with carbon, that even when there is no fog, particles can be collected on Pouchet's aëroscope when only a very small quantity of air is drawn through.

It is apparently chiefly from combustion, and in some cases from chemical works, that the air of towns contains so much acid as to make rain-water acid. In Manchester, in 1868, Angus Smith found the rains to contain from 8 to 2 of sulphuric acid (free and combined), and from 1·824 to 0·041 of hydrochloric acid per 100,000 parts. In Liverpool and Newcastle air the same thing occurs; the sulphuric acid is always larger in amount than the hydrochloric.

Sulphurous and sulphuric acids also appear to be less rapidly removed, as Angus Smith found a perceptible quantity in the air of Manchester; and the rain-water is often made acid from this cause.

The products of gas combustion are for the most part allowed to escape into rooms, but certainly this should not be allowed when gas is burnt in the large quantities commonly used. The immense quantity of gas often used causes great heat, humidity of the air, and there is also some sulphur dioxide, an excess of carbon dioxide, and, probably, a little carbon monoxide, to which some of the effects may be due. Weaver[1] found as much as 5·32 volumes of carbon dioxide per 1000 in the room of a frame-work knitter in Leicester, with 14 gas-lights burning. In other workrooms the amounts were 5·28, 4·6, down to 2·11 volumes per 1000. This amount has a very injurious effect on health, as shown long ago by Dr Guy. In a workshop in Paris, with 400 men and 400 gas-burners, the health of the men was very bad. General Morin introduced good ventilation, and the number of cases of illness was reduced one-third. The appetite of the men, formerly very bad, greatly improved. According to Dr Zock,[2] coal gas gives off rather more carbon dioxide for an equal illuminating power than oil, but less than petroleum. Dr Odling found, for equal illuminating power, that candles gave more impurity to the air than gas.[3] Gas gives out, however, more water.

Carnelley and Mackie[4] show that the combustion of coal exercises a marked effect on the organic matter in the air of towns; but that the combustion of coal gas in a room has not much effect in increasing the organic matter, whereas a burning oil lamp has a marked effect.

In tobacco smoke are contained particles of nicotine or its salts (Heubel), and probably of picoline bases. There is also much carbon dioxide, ammonia, and butyric acid.

Dr Ripley Nichols has investigated the air in smoking cars on American railways, and found the CO_2 to range from 0·98 to 3·35 per 1000, with a mean of 2·278 : in ordinary non-smoking cars the CO_2 varied from 1·74 to 3·67, with a mean of 2·32, so that there was not much difference as far as CO_2 went. As regards ammonia, however, the difference was great, for (taking the external air ratio as 100) he found in the smoking car from 310

[1] *Lancet*, July 1872.
[2] *Zeitsch. für Biol.*, Band ii. p. 117 (1866).
[3] *Medical Times and Gazette*, Jan. 9, 1869.
[4] *Proc. Roy. Soc.*, vol. xli.

to 575, whilst in the ordinary ears it was only 135 to 175. None of the peculiar products of the combustion of tobacco were found.[1]

Air vitiated by Effluvia from Sewage Matter and Air of Sewers.

Air of Cesspools.—The air of cesspools, and especially of the cemented pits which are still common in many continental towns, and which receive little beyond the solid and liquid excreta and some of the house water, is generally highly impure. Lévy[2] refers to an extreme case, in which the oxygen was lessened to 20 per 1000, the nitrogen being 940 and the CO_2 40. In this case apparently no other gases were present; but in most instances there is a variable amount of hydrogen sulphide,[3] ammonium sulphide, nitrogen, carbon dioxide, and carburetted hydrogen, in addition to fœtid organic matters. These organic matters are in large amount; 62 feet of the air of a cesspool destroyed, in Angus Smith's experiments, as much potassium permanganate as 176,000 cubic feet of pure air, though perhaps some hydrogen sulphide may have been also present. Oesterlen[4] states that these gases will pass easily through walls; and M. Hennezel[5] noticed that in the "fosses d'aisances" in Paris, even in those covered with stone slabs and earth, the wind blowing down the ventilating tube will force the gas through the neighbouring walls, and then perhaps into the house.

The Air of Sewers.—In sewers the products of decomposition are variable, as not only solid and liquid excreta and house water, but the washings and débris of the streets, the refuse of trades, &c., pass into the sewers. As a rule, the products of decomposition of the sewer water appear to be much the same as noted above—viz., fœtid organic matters, carbo-ammoniacal substances condensing with the water of the air on the cold walls, carbon dioxide, nitrogen, and hydrogen sulphide.[6] The proportions of these gases are variable;[7] the most common are carbon dioxide and nitrogen; marsh gas is found when oxidation is impeded, and hydrogen sulphide and ammonium sulphide, which form in the sewer water in most cases, are liberated from time to time. The gases, however, are, as a rule, of far less importance than the fœtid organic matters, the exact nature of which it would be most desirable to examine more thoroughly.

The organic vapour is carbo-ammoniacal; the putrid substance in the sewer water appears, from Odling's observations, to be allied to the compound ammonias; it contains more carbon than methylamine ($NH_2(CH_3)$) and less than ethylamine ($NH_2(C_2H_5)$).

The composition of sewer air will, of course, vary infinitely with the amount of gases disengaged and the degree of ventilation in the sewer. The quantity of oxygen is sometimes in normal amount; it may, however, be diminished in very badly constructed sewers. Parent-Duchâtelet gave an analysis of the air of a choked sewer in Paris, which contained only 137·9 per 1000 of oxygen,[8] and no less than 29·9 per 1000 of hydrogen sulphide.

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[1] Reprint from the *Sixth Annual Report of the Massachusetts Board of Health.*
[2] *Traité d Hygiène*, 3rd edit., p. 636.
[3] Barker, *On Malaria and Miasmata*, p. 245.
[4] Oesterlen, *Hygiene*, 1857, p. 445.
[5] *Ann. d'Hygiène*, Oct. 1868, p. 178.
[6] Oesterlen, *Handb. der Hyg.*, 2nd edition, p. 445.
[7] Dr Letheby's experiments, as given in his official Report, in his article in the *Encyclopædia Britannica*, 8th edition (Sanitary Science), &c., and in a letter to Dr. Adams (given by Dr Adams in his pamphlet, *The Sanitary Aspect of the Sewage Question*, 1868, p. 34), are the most complete on this subject.
[8] *Hygiène publ.*, t. i. p. 209, footnote, and p. 390.

Excluding this analysis, the greatest impurity in the old Parisian sewers, as determined by Gaultier de Claubry, in 19 analyses[1] in 1829, was 34 per 1000 of carbon dioxide and 12·5 per 1000 of hydrogen sulphide (in different samples of air). The lowest amount of oxygen was 174 per 1000. Hydrogen sulphide was present in 18 out of 19 cases, the mean of the whole 19 cases being 8·1 per 1000. The mean amount of CO_2 in 19 cases was 23 per 1000. In the present London sewers of good construction the air is much less impure. Dr Letheby found only 5·32 per 1000 of CO_2, a good deal of ammonia, and only traces of hydrogen sulphide and marsh gas. Dr Miller's experiments in 1867[2] gave a mean of only 1·06 per 1000 of CO_2 in 18 analyses, and 3·07 per 1000 in 6 other instances, the oxygen 207·1 per 1000. No hydrogen sulphide was present. Dr Russell examined the air in the sewers of Paddington in August; the most impure air contained 207 oxygen, 787·98 nitrogen, and 5·1 volumes of CO_2 per 1000; there was very little ammonia, and no hydrogen sulphide.

It is evident that, if we take the carbon dioxide and hydrogen sulphide as indices, sewer air has no constant composition. It is sometimes almost as pure as the outside air, while at other times it may be highly impure. But these gases are probably the least important ingredients of sewer air; that organic matters are present is evident from the peculiar fœtid smell, and in some cases they are in large amount; 8000 cubic feet of the air of a house into which sewer air had penetrated destroyed more than 20 times as much potassium permanganate as the same quantity of pure air (Angus Smith). *Fungi* and *bacteria* grow rapidly in such air, and meat and milk soon taint when exposed to it. When the sewer air passes through charcoal these substances are absorbed; they may be partly oxidised, as Dr Miller found some nitric acid in the charcoal, but they also collect in the charcoal, and can be recovered (in part at any rate) from it by distillation.[3]

We must also suppose, for facts leave us no other explanation, that the unknown agencies (perhaps *bacteria*) which produce enteric fever may also be present, and there can be little doubt that cholera[4] may occasionally spread in the same way. The poison of yellow fever (as appears likely from the epidemic in Madrid) may also exist in sewer air. Whether small-pox, scarlet fever, &c., can own a similar channel of distribution is uncertain, although they are no doubt aggravated by it; that dysentery and diarrhœa may also be caused by exhalations proceeding from a foul sewer we cannot doubt, but the precise agency is here also unknown.

The experiments of Professor Frankland[5] show that solid or liquid matter is not likely to be scattered into the air from the sewage itself by any agitation it is likely to undergo, until gas begins to be generated in it. He found that no ordinary agitation (even greater than sewer water is likely to meet with) would scatter particles of lithia solution into the air, but that the bursting of bubbles of carbon dioxide was sufficient to effect it. Hence he argues (with apparent truth) that sewage becomes dangerous in this way only after the setting in of decomposition, so that if we take proper steps to carry away sewage at once the danger becomes reduced to a minimum.

Dr D. D. Cunningham found large quantities of *bacteria* in the air of the Calcutta sewers.

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[1] Parent-Duchâtelet's *Hyg. publique*, t. i. p. 389.

[2] Abstract in *Chemical News*, March 1868.

[3] Miller, *Chemical News*, March 1868.

[4] A case in which sewers probably played a part in the dissemination of cholera is given in Dr Parkes' *Report on the Cholera in Southampton in* 1866 *to the Medical Officer of the Privy Council.*

[5] *Proceedings of the Royal Society*, 1877.

Air of Churchyards and Vaults.

The decomposition of bodies gives rise to a very large amount of carbon dioxide. It has been calculated that, when intramural burial was carried on in London, 2½ millions of cubic feet of CO_2 were disengaged annually from the 52,000 bodies then buried. Ammonia and an offensive putrid vapour are also given off. The air of most cemeteries is richer in CO_2 than ordinary air (0·7 to 0·9 per 1000, Ramon da Luna), and the organic matter is perceptibly larger when tested by potassium permanganate. In vaults, the air contains much CO_2, carbonate or sulphide of ammonium, nitrogen, hydrogen sulphide, and organic matter (Pellieux). Waller Lewes found little SH_2 or CH_4, or cyanogen, or hydrogen phosphide. In his experiments the gas always extinguished flame.

Fungi and germs of *infusoria* abound.

Air vitiated by certain Trades.

Hydrochloric acid gas, from alkali works.

Sulphur dioxide and sulphuric acid, from copper works—bleaching.

Hydrogen sulphide, from several chemical works, especially of ammonia.

Carbon dioxide, carbon monoxide, and hydrogen sulphide, from brick-fields and cement-works.

Carbon monoxide (in addition to above cases), from iron furnaces, may amount to from 22 to 25 per cent. (Letheby); from copper furnaces, 15 to 19 per cent. (Letheby).

Organic vapours, from glue refiners, bone-burners, slaughter-houses, knackeries.

Zinc fumes (oxide of zinc), from brassfounders.

Arsenical fumes, from copper-smelting.

Phosphoric fumes, from manufacture of matches.

Carbon disulphide, from some india-rubber works.

Air of Towns.

The air of towns may be vitiated by respiration, combustion, effluvia from the soil, sewers, and trades. The movement of the air tends, however, to continually dilute and remove these impurities, and the heavier particles deposit, so that the air even of manufacturing towns is purer than might have been anticipated. The amount of oxygen in the atmosphere in the purest air near the surface of the earth, being taken as from 209 to 209·9 per 1000 volumes, and the carbon dioxide being from 0·3 to 0·45 per 1000, with a mean of 0·4, it would appear, from Angus Smith's observations,[1] that in a crowded part of Manchester, exposed to smoke, the amount of oxygen was from 208·68 to 201·79 per 1000; the average of the street air taken from the laboratory front door was, in Manchester, 209·43; of the closet, a midden behind the laboratory, 207. In the London air, in the open spaces, the oxygen amounted to 209·5; in the crowded eastern districts to 208·57.[2] In a foggy frost, in Manchester, when the smoke was not moving much, the amount was 209·1. In Glasgow the average was 209·092. The variations are, therefore, within narrow limits.

The percentage lessening of oxygen in atmospheric air is partly made up

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[1] *Air and Rain*, p. 24.

[2] A. Smith, *op. cit.*, p. 30.

by an increase in the carbon dioxide; but if a town is well built, the increase is trifling; the mean amount of CO_2 for London, in Roscoe's experiments, was only 0·37 per 1000 volumes; in Manchester, in usual weather, A. Smith found the amount 0·403 per 1000; during fogs, 0·679; in the air above the middens, 0·774 per 1000. It is stated that there is a difference between close and open spaces in towns; thus, in the open spaces (parks) in London, the mean amount in A. Smith's experiments was 0·301 per 1000; in Newgate Street (in the City), it was 0·413; in Lower Thames Street (City), 0·428 per 1000. It is not, however, stated whether the observations were made simultaneously. In the neighbourhood of St Mary's Hospital, Paddington, Dr de Chaumont found the mean CO_2 to be 0·560, in damp still weather, July 1875; the same locality in dry, hot weather, with a good deal of movement of air, 0·416 per 1000 (Aug. 1876); in the neighbourhood of University College Hospital, damp weather, 0·736 per 1000, in February 1877. In Glasgow, the average CO_2 was 0·502, and in Perth 0·416 per 1000.[1] In Dundee it was 0·390, there being a slight difference between night and day, but only 0·280 in the suburbs (Carnelley, Haldane, and Anderson). In foreign cities the amount is greater, and surpasses the normal limit in air. In Madrid, Ramon da Luna found 0·517 as a mean average, and in some cases 0·8 per 1000; in Munich, the amount is 0·5 per 1000. These numbers seem, after all, insignificant, but they are not really so, as the aggregate difference, if only 0·1 per 1000, is considerable. In the air of towns which burn coal there are also, as noted, an excess of acidity (sulphuric and hydrochloric acids), and various suspended matters, which no doubt have injurious effects.[2]

The air of most towns, in addition to ammonia, also contains a nitrogenous substance which, when condensed in pure water, can be made to yield albuminoid ammonia by Wanklyn's method. In various places in London A. Smith[3] found the amount to average 0·1509 milligrammes of albuminoid ammonia in 1 cubic metre. The greatest amount was in a field 2 miles past Clapham Junction (viz., 0·27108 milligrammes per cubic metre), and the least was in Westminster Abbey yard (0·0855 milligrammes). At the shore at Innellan (Firth of Clyde), the amount was 0·1378 milligrammes, and the mean in the streets of Glasgow was 0·3049 milligrammes per cubic metre. In the air of the Underground Railway, in London, the amount was 0·3734 milligrammes. In the garden of St Mary's Hospital, Paddington, Dr de Chaumont found 0·5280 and 0·5206 mgms. per c.m. (see p. 143) In the back yard of University College Hospital, 0·2060 and 0·3675. The mean of Mr Moss's experiments in the open air of Portsmouth was rather less, viz., 0·0886 milligrammes of albuminoid ammonia per cubic metre. This ammonia may be derived from the living beings in the air, or from dead organic matter; and to bring out the full meaning of such researches, the chemical must be supplemented by a microscopical examination with cultivation experiments. Ozone is generally absent in town air, but Marié-Davy found at Montsouris an average of 0·0115 milligrammes per cubic metre.[4] This, however, depends very much upon the situation of the observatory and the direction of the prevailing winds. The wind blowing from the open country is richer in ozone than that coming from the town.[5]

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[1] A. Smith, *Air and Rain*, p. 50 *et seq.*

[2] There are also nitrous and nitric acids, due probably to the oxidation of organic matters.

[3] *Air and Rain*, p. 437. The results are stated in milligrammes per cubic metre, instead of grammes per million cubic metres.

[4] *Annuaire de l'Observatoire de Montsouris pour l'an* 1882.

[5] See Fodor, *Die Luft*, p. 84, 1881.

These observations prove how important it is to build towns in such a way as to ensure good perflation and movement of air everywhere, and to provide open spaces in all the densely-crowded parts. The great powers of nature, winds, and the fall of rain, will then, for the most part, keep the atmospheric impurities within limits not injurious to health.

Air of Marshes.

The air of typical marshes contains usually an excess of carbon dioxide, which amounts perhaps, to 0·6 or 0·8 or more per 1000 volumes. Watery vapour is usually in large quantity. Hydrogen sulphide is present, if the water of the marsh contains sulphates, which in presence of organic matter are converted into sulphides, from which SH_2 is derived by the action of vegetable acids. Marsh gas is also often present, and occasionally free hydrogen and ammonia, and, it is said, hydrogen phosphide.[1]

Organic matter also exists in considerable quantity. Discovered by Vauquelin (1810 and 1811, in the air collected over the Languedoc marshes), by De Lisle, and again by Moscati (1818, in the air of a Lombardy rice-field), and examined more recently by Boussingault (1829, 1839), Gigot (1859), and Becchi (1861), the organic matter seems to have much the same character always. It blackens sulphuric acid when the air is drawn through it; gives a reddish colour to nitrate of silver; has a flocculent appearance, and sometimes a peculiar marshy smell, and, heated with soda-lime, affords evidence of ammonia. The amount in Becchi's experiments was 0·00027 grammes in a cubic metre of air (= 0·000118 grains in 1 cubic foot). Ozone, led through a solution of this organic matter, did not destroy it. It is said to destroy quinine. Besides the organic matter, various vegetable matters and animals, floating in the air, are arrested when the air of marshes is drawn through water or sulphuric acid, and débris of plants, *infusoria*, insects, and even, it is said, small *crustacea* are found; the ascensional force given by the evaporation of water seems, indeed, to be sufficient to lift comparatively large animals into the air. Dr M. P. Balestra[2] has described spores and sporangia of a little algoid plant in the air of Rome and its vicinity, and the same plant is found abundantly in the water of the marshes near Rome. Balestra is inclined to attribute marsh fever to this widely-diffused "microphyte granule"; whilst the researches of Klebs and Tommasi-Crudeli have led them to attribute it to a form of *bacillus*, which they have called *B. malariæ*.[3] It has been stated that ozone is deficient in the air over marshes, but the observations of Burdel[4] do not confirm this. He often found as much ozone as in other air. In the air collected from the surface of lakes containing some aquatic plants, especially *Chara*, there is a large proportion of oxygen, and this air gives, near the surface, the reaction of ozone (Clemens), while at some feet above the reaction is lost. This is usually ascribed to the oxidation of organic matter, which rises simultaneously from the water.

Air in the Holds of Ships.

The air in the holds of ships is compounded of exhalations from the wood, bilge-water, and cargo. Owing to the comparative immobility of the air, it

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[1] Toropoff (of St Petersburg) considers malaria poison gaseous; after removing water, oxygen, and carbon dioxide, he found marsh air still yielded 84 to 89 per cent. of gaseous matter, whilst hill air gave only 81.

[2] *Comptes Rendus*, 1870, No. 3, July, p. 235.

[3] *Studii sulla Natura della Malaria*, *Roma*, 1879.

[4] *Recherches sur les fièvres paludéennes*, 1858.

often becomes extremely foul. The composition is not known, but the smell of hydrogen sulphide is very perceptible, and white paint is blackened. In some cases, when the water-tanks are filled with condensed water from the engines, which is not well cooled, the hold may become extremely hot (100° to 120° Fahr.), and decomposition be much increased.

Air in Mines.

In the metalliferous mines the air, according to Angus Smith,[1] is poor in oxygen (205 per 1000 sometimes) and very rich in carbon dioxide (7·85 per 1000 volumes on a mean of many experiments). It also contains organic matter, giving, when burnt, the smell of burnt feathers, in uncertain amount. These impurities arise from respiration, combustion from lights, and from gunpowder blasting. This latter process adds to the air, in addition to carbon dioxide, carbon monoxide, hydrogen and hydrogen sulphide, various solid particles, consisting of suspended salts, which may amount to as much as 6 or 7 milligrammes in each cubic metre of air. These suspended substances are principally potassium sulphate, carbonate, hyposulphite, sulphide, sulphocyanide, and nitrate, carbon, sulphur, and ammonium sesquicarbonate.

Much of this may hereafter be avoided by the new process of getting coal, by means of compressed quicklime, which is slaked in holes drilled in the coal.

SECTION II.

DISEASES PRODUCED BY IMPURITIES IN AIR.

SUB-SECTION I.—SUSPENDED SOLID MATTERS.

1. *Inorganic and Inanimate Substances.*—The effect which is produced on the respiratory organs by substances inhaled into the lungs has long been known. Ramazzini and several other writers in the last century, and Thackrah more than fifty years ago in this country, directed special attention to this point, and since that time a great amount of evidence has accumulated,[2] which shows that the effect of dust of different kinds in the air is a far more potent cause of respiratory diseases than usually admitted. Affections of the digestive organs are also caused, but in a much slighter degree. The respiratory affections are frequently recurring catarrhs (either dry or with expectoration) and bronchitis, with subsequent emphysema, although this sequence appears from the figures given by Hirt to be not quite so frequent as was supposed, perhaps from the cough not being violent. Acute pneumonia, and especially chronic non-tubercular phthisis, are also produced. The suspended matters in the air which may produce these affections may be mineral, vegetable, or animal; but it would seem that the severity of the effects is chiefly dependent on the amount of dust, and on the physical conditions as to angularity, roughness, or smoothness of the particles, and not on the nature of the substance, except in some special cases. A large number of the unhealthy trades are chiefly so from

[1] *Report on Mines*, Blue Book, 1864.

[2] The whole subject has been very carefully investigated by Hirt. *Die Krankheiten der Arbeiter*, Erste Theil, *Staubinhalations-Krankheiten*, von Dr L. Hirt, 1871. See also Eulenberg, *Gewerbe Hygiene*, 1876. Also Pettenkofer and Ziemssen's *Handbuch der Hygiene und Gewerbe Krankheiten*.

this cause; this is the case, in fact, with miners of all kinds.[1] Sir J. Simon[2] states that, with one exception, the 300,000 miners in England break down as a class prematurely from bronchitis and pneumonia caused by the atmosphere in which they live. The exception is most important. The colliers of Durham and Northumberland, where the mines are well ventilated, do not appear to suffer from an excess of pulmonary disease, or do so in a slight degree only. In different mines, also, the amount of pulmonary disease is different, apparently according to the amount of ventilation.

The following table is given by the Registrar-General:[3]—

Average Annual Deaths per 1000 *from Pulmonary Disease during the Years* 1860–62 *inclusive.*

Ages.	Metal Miners in Cornwall.	Metal Miners in Yorkshire.	Metal Miners in Wales.	Males, exclusive of Miners, in Yorkshire.
Between 15 and 25 years,	3·77	3·40	3·02	3·97
,, 25 ,, 35 ,,	4·15	6·40	4·19	5·15
,, 35 ,, 45 ,,	7·89	11·76	10·62	3·52
,, 45 ,, 55 ,,	19·75	23·18	14·71	5·21
,, 55 ,, 65 ,,	43·29	41·47	35·31	7·22
,, 65 ,, 75 ,,	45·04	53·69	48·31	17·44

The enormous increase of lung diseases among the miners after the age of 35 is seen at a glance.

In the pottery trade all classes of workmen are exposed to dust, especially however the flat-pressers. So common is emphysema that it is called "the potters' asthma."

So also among the china scourers; the light flint dust disengaged in great quantities is a "terrible irritant." Dr Greenhow states that *all* sooner or later become "asthmatical."

The grinders of steel, especially of the finer tools, are perhaps the most fatally attacked of all, though of late years the evil has been somewhat lessened by the introduction of wet-grinding in some cases, by the use of ventilated wheel-boxes, and by covering the work with linen covers when practicable. The wearing of masks and coverings for the mouth appears to be inconvenient, otherwise there is no doubt that a great amount of the dust might be stopped by very simple contrivances.[4]

Button-makers, especially the makers of pearl buttons, also suffer from chronic bronchitis, which is often attended with hæmoptysis. So also pin-pointers, some electro-plate workmen, and many other trades of the like kind, are more or less similarly affected.

In some of the textile manufactures much harm is done in the same way. In the carding rooms of cotton, and wool, and silk spinners, there is a great

[1] Thackrah enumerates the following in his work on the *Effects of Arts, Trades, and Professions on Health*, 1832, p. 63:—The workmen who were affected injuriously by the dust of their trades 50 years ago, and the same list will almost do for the present day: Corn-millers, maltsters, teamen, coffee-roasters, snuff-makers, papermakers, flock-dressers, feather-dressers, shoddy-grinders, weavers of coverlets, weavers of harding, dressers of hair, hatters employed in the bowing department, dressers of coloured leather, workers in flax, dressers of hemp, some workers in wood, wire-grinders, masons, colliers, iron miners, lead miners, grinders of metals, file-cutters, machine-makers, makers of firearms, button-makers. Hirt (*op. cit.*) also gives an extended table.

[2] *Fourth Report of the Medical Officer of the Privy Council*, 1862, p. 15 *et seq.* See also Arlidge, in *B. and F. Med. Chir. Rev.*, July 1864, for the effects of the pottery trade.

[3] *Report of the Commissioners on Mines*, Blue Book, 1864.

[4] See for further particulars and much interesting information Dr Hall's paper read at the Social Science Congress in 1865.

amount of dust and flue, and the daily grinding of the engines disengages also fine particles of steel. Since the cotton famine, a size composed in part of china clay (35·35 grains of clay in 100 of sizing on an average) has been much used in cotton mills, and the dust arising seems certainly to be producing injurious effects on the lungs of the weaver.[1]

In flax factories a very irritating dust is produced in the process of hackling, carding, line preparing, and tow-spinning. Of 107 operatives, whose cases were taken indiscriminately by Dr Greenhow, no less than 79 were suffering from bronchial irritation, and in 19 of these there had been hæmoptysis. Among 27 hacklers, 23 were diseased.[2] In shoddy factories, also, the same thing occurs. These evils appear to be entirely and easily preventible. In some kinds of glass-making, also, the workmen suffer from floating particles of sand and felspar, and sometimes potash or soda-salts.

The makers of grinding-stones suffer in the same way; and children working in the making of sand-paper are seriously affected, sometimes in a very short time, by the inhalation of fine particles of sand into the lungs.

In making Portland cement, the burnt masses of cement are ground down and then the powder is shovelled into sacks; the workmen doing this cough a great deal, and often expectorate little masses of cement. Some of them have stated that if they had to do the same work every day it would be impossible to continue it on account of the lung affection. Sir Charles Cameron has called attention to the fatal effects of vapours of silicon fluoride in making superphosphate; it forms a gelatinous deposit on the mucous membrane of the air passages, and causes death by suffocation.[3]

The makers of matches, who are exposed to the fumes of phosphorus, suffer from necrosis of the jaw, if there happens to be any exposed part on which the fumes can act. This, however, is now obviated by the use of amorphous or red phosphorus, which is harmless.

In making bichromate of potash, the heat and vapour employed carry up fine particles, which lodge in the nose and cause great irritation, and finally ulceration, and destruction of both mucous membrane and bone. Those who take snuff escape this. The mouth is not affected, as the fluids dissolve and get rid of the salt. The skin is also irritated if the salt is rubbed on it, and fistulous sores are apt to be produced. No effect is noticed to be produced on the lungs.[4] Washing the skin with subacetate of lead is the best treatment.

In the process of sulphuring vines the eyes often suffer, and sometimes (especially when lime is used with the sulphur) decided bronchitis is produced.

In some trades, or under special circumstances, the fumes of metals, or particles of metallic compounds, pass into the air. Brassfounders suffer from bronchitis and asthma, as in other trades in which dust is inhaled; but in addition they also suffer from the disease described by Thackrah as "brass ague," and by Dr Greenhow as "brassfounder's ague." It appears to be produced by the inhalation of fumes of zinc oxide;[5] the symptoms

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[1] G. Buchanan's *Report on certain Sizing Processes used in the Cotton Manufacture at Todmorden*. Ordered to be printed by the House of Commons, May 1872.

[2] Sir J. Simon's *Fourth Report*, p. 19.

[3] *On the Toxicity of Silicon Fluoride*, by Sir Charles A. Cameron, M.D., &c., reprinted from the *Dublin Journal of Medical Science*, January 1887.

[4] Chevallier, *Ann. d'Hygiène*, July 1863, p. 83.

[5] Some doubt has been expressed as to those symptoms being produced by *pure* zinc fumes; see Hirt (*op. cit.*), who says that men employed in making zinc houses, where they inhale *pure* zinc fumes without copper, never suffer from brassfounder's ague. On the other hand, he describes very graphically the effect of the metallic fumes (copper?) on himself. The workmen think that drinking large quantities of milk lessens the severity of the attacks.

are tightness and oppression of the chest, with indefinite nervous sensations, followed by shivering, an indistinct hot stage, and profuse sweating. These attacks are not periodical.

Coppersmiths are affected somewhat in the same way, by the fumes arising from the partly volatilised metal, or from the spelter (solder).

Tinplate workers also suffer occasionally from the fumes of the soldering.

Plumbers inhale the volatilised oxide of lead which rises during the process of casting. Nausea and tightness of the chest are the first symptoms, and then colic and palsy.

Manufacturers of white lead inhale the dust chiefly from the white beds and the packing.

House painters also inhale the dust of white lead to a certain extent, though in these, as in former cases, much lead is swallowed from want of cleanliness of the hands in taking food.

Workers in tobacco factories suffer in some cases, and there are persons who can never get accustomed to the work; yet with proper care and ventilation it appears[1] that no bad effects ordinarily result.

Workers in mercury, silverers of mirrors, and water gilders (men who coat silver with an amalgam of mercury and gold) are subject to mercurialismus. But electricity has rendered gilding with the aid of mercury to some extent obsolete; and the making of mirrors with nitrate of silver may perhaps ultimately abolish all the horrors of mercurial labour.

Workmen who use arsenical compounds, either in the making of wall papers or of artificial flowers, &c., suffer from slight symptoms of arsenical poisoning, and many persons who have inhaled the dust of rooms papered with arsenical papers have suffered from both local and constitutional effects,—the local being smarting of the gums, eyes, nose, œdema of the eyelids, and little ulcers on the exposed parts of the body; the constitutional being weakness, fainting, asthma, anorexia, thirst, diarrhœa, and sometimes even severe nervous symptoms.[2] Arsenic has been detected in the urine of such persons.

A. Manouvriez[3] gives an account of the diseases among workmen in France employed in making patent fuel, a mixture of coal-dust and pitch. He says they suffer from melanodermy, cutaneous eruptions, and epithelial cancers, affections of the eyes, ears, and nose; bronchitis with pulmonary pseudomelanosis; and gastro-entero-hepatic disorders. Hirt also mentions some of the diseases produced among workmen by the various tar-products.

2. *Living Substances, as Infusoria, Fungi, Algæ, or their Germs, or Pollen or Effluvia of Flowers.*—That summer catarrh or hay-fever is produced in many persons by the pollen from grasses (especially *Anthoxanthum odoratum*), trees, or flowers is now generally admitted. The researches of Dr Blackley,[4] of Manchester (himself a sufferer), have placed the matter beyond a doubt. In his case, at least, it was pollen that produced the disease, and not the effluvia merely. Coumarin had no effect. Grass-pollen (which constitutes 95 per cent. of the pollen floating in the atmosphere) and the pollen from pine-trees were the most powerful in effect. Curiously enough, the pollen of poisonous plants, such as the Solanaceæ, was often comparatively innocuous. It is also known that the spores of certain *fungi*, in falling on a proper soil, may cause disease of the skin in men, and that *Tinea* and *Favus* are thus sometimes spread seems certain. There is a growing belief in the

[1] Hirt, *op. cit.*, p. 162, 163.
[2] See paper by Mr Jabez Hogg, *Sanitary Record*, April 25, 1879.
[3] *Annales d'Hygiène*, March 1876.
[4] *Op. cit.*

connection of the specific diseases with low vegetable forms. Dr Salisbury, of Ohio, attempted to trace ague to a *Palmella;* others have ascribed it to the *Oscillarineæ* generally; Dr Balestra believes that a special *alga* is the efficient cause, and Klebs and Tommasi-Crudeli attribute it to *Bacillus malariæ*.

Dr Salisbury has also affirmed that the prevalence of measles in the Federal army arose from *fungi* from mouldy straw. He inoculated himself, his wife, and forty other persons with the *fungi*, and produced a disease like measles in from twenty-four to ninety-six hours. It is stated also that this disease was protective against measles. Dr Woodward (United States Army) has repeated Dr Salisbury's experiments, but does not confirm them.[1]

Professor Hallier, of Jena, has to some extent adopted the view that *fungi* give rise to some of the specific diseases, and that the spores float in the air, and are thus communicated, but the proofs are not satisfactory.[2]

Dr D. D. Cunningham says that he was unable to connect any disease, in Calcutta, with the occurrence of *bacteria* or other bodies in the air, either as regards variation in kind or in quantity.

Blackley found that *Chaetonium elatum* (bristle mould) produced nausea, fainting, and giddiness, and the spores of *Penicillium* (inhaled) brought on hoarseness, going on to complete aphonia: the condition lasted two days, and ended in a sharpish attack of catarrh.

Pettenkofer, Von Nägeli, Fodor, and many others distinctly attribute specific diseases to *bacteria* of certain kinds. The connection of the wool-sorters' disease with the existence of a *bacillus* (*Bacillus anthracis*) in the body of the patient has been established, and this is in all probability inhaled from the atmosphere in which the men work.

Koch has recently demonstrated the presence of a *bacillus* (*Bacillus tuberculosis*) in cases of phthisis, and has apparently succeeded in cultivating it, and propagating the disease by that means.

3. *The Contagia.*—Under this head it will be convenient to include the unknown causes of the specific diseases. That these in some cases (scarlet fever, smallpox, measles, typhus, enteric fever, plague, pertussis, yellow fever, influenza, &c.) reach the person through the medium of air (as well as in some cases through water or food) cannot be doubted. Some of these contagia have in some way a power of growth and multiplication in the body of a susceptible animal, but whether they can find nourishment, and thus grow, in the air is yet doubtful. It seems clear, however, that they can retain the powers of growth for some time, as the smallpox and scarlet fever poisons may infect the air of a room for weeks, and cattle plague and enteric fever poisons will last for months,[3] and in this they resemble *Protococci* and other low forms of life, which can be dried for years and yet retain vitality.

The exact condition of the agency is unknown; whether it is in the form of impalpable particles, or moist or dried epithelium and pus cells, is a point for future inquiry; and whether it is always contained in the substances discharged or thrown off from the body (as is certainly the case in smallpox), or is produced by putrefactive changes in those discharges, as is supposed to

[1] *Camp Diseases in the U.S. Army*, p. 27. The fungus is a *Penicillium*.

[2] Many papers on this subject by Hallier and others are contained in Hallier's *Zeitschrift für Parasitenkunde*.

[3] The long retention of power by the enteric fever poison is shown by a case related by Dr Becher (*Army Medical Department Report*, vol. x. p. 237). The enteric poison appears to have adhered to the walls and ceiling, and to have retained its power to excite disease in another person for a month; it was not destroyed by the heat of a very hot Indian station (Gwalior) in February.

be the case in cholera and dysentery, is also a matter of doubt. Bakewell[1] collected dust deposited at a height of 7 or 8 feet in smallpox wards, which contained the minute scabs with the epidermic scales and variolous corpuscles which are thrown off from the skin in smallpox. Some modern expositors of the old doctrine of fomites would consider these organic matters to be inconceivably minute particles of living, or to use Dr Beale's phrase, bioplastic matter, which is capable, he believes, of wonderfully rapid growth under proper conditions.[2] But it is also probable that some, if not all, the disease poisons are really living organisms, a view very widely received now both in this country and elsewhere.

The specific poisons manifestly differ in the ease with which they are oxidised and destroyed. The poison of typhus exanthematicus is very readily got rid of by free ventilation, by means of which it must be at once diluted and oxidised, so that a few feet give, under such circumstances, sufficient protection. This is the case also with the poison of oriental plague, while, on the other hand, the poisons of smallpox and scarlet fever will spread in spite of very free ventilation, and retain their power of causing the same disease for a long time. In the case of malaria the process of oxidisation must be slow, since the poison can certainly be carried for many hundred yards, even sometimes for more than a mile in an upward direction (up a ravine, for instance), or horizontally, if it does not pass over the surface of water. The poison of cholera, also, some have supposed, can be blown by the winds for some distance; but the most recent observations on its mode of spread lead to the conclusion that the portability of the poison in this way has been greatly overrated. The poison of diphtheria appears also to be transported some distance by wind.

But the specific poisons are not the only suspended substances which thus float through the atmosphere.

There can be no doubt that while purulent and granular ophthalmia most frequently spread by direct transference of the pus or epithelium cells, by means of towels, &c., and that erysipelas and hospital gangrene, in surgical wards, are often carried in a similar way, by dirty sponges and dressings, another mode of transference is by the passage into the atmosphere of disintegrating pus cells and putrefying organic particles, and hence the great effect of free ventilation in military ophthalmia (Stromeyer), and in erysipelas[3] and hospital gangrene. In both these diseases great evaporation from the walls or floor seems in some way to aid the diffusion, either by giving a great degree of humidity or in some other way. The practice of frequently washing the floors of hospitals is well known to increase the chance of erysipelas, and this might be explained, as Von Nägeli suggests, by the moisture and subsequent drying helping the development and subsequent dissemination of minute organisms.

Sub-Section II.—Gaseous Matters.

(*a*) *Carbon Dioxide.*—The normal quantity of CO_2 being 0·3 to 0·4 volumes per 1000, it produces fatal results when the amount reaches from 50 to 100 per 1000 volumes; and at an amount much below this, 15 to 20 per 1000, it produces, in some persons at any rate, severe headache. Other persons can inhale, for a brief period, considerable quantities of carbon

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[1] *Med. Times and Gazette*, Dec. 7, 1872.

[2] See chapter on Disinfection for a fuller notice of these points.

[3] See Dr F. de Chaumont's *Reports on St Mary's Hospital, loc. cit.*

dioxide without injury;[1] and animals can be kept for a long time in an atmosphere highly charged with it, provided the amount of oxygen be also increased. In the air of respiration, headache and vertigo are produced when the amount of CO_2 is not more than 1·5 to 3 volumes per 1000; but then organic matters, and possibly other gases, are present in the air, and the amount of oxygen is also lessened. Well-sinkers, when not actually disabled from continuing their work by CO_2, are often affected by headache, sickness, and loss of appetite; but the amount of CO_2 has never been determined.

The effect of constantly breathing an atmosphere containing an excess of CO_2 (up to 1 or 1·5 per 1000 volumes) is not yet perfectly known. Dr Angus Smith[2] attempted to determine its effect *per se*, the influence of the organic matter of respiration being eliminated. He found that 30 volumes per 1000 caused great feebleness of the circulation, with, usually, slowness of the heart's action; the respirations were, on the contrary, quickened, but were sometimes gasping. These effects lessened when the amount was smaller, but were perceptible when the amount was as low as 1 volume per 1000—an amount often exceeded in dwelling-houses. At the same time, this is not the case always, for in the air of a soda-water manufactory, when CO_2 was 2 per 1000, Smith found no discomfort to be produced. The effects noticed by Smith have not been observed in experiments on animals by Demarquay, W. Müller, and Eulenberg,[3] nor in other cases in men, as in the bath at Oeynhausen, where no effect is produced by the air of the room in which the bathers remain for 30 to 60 minutes, although it contains a large percentage. It has been supposed that lung diseases, especially phthisis, are produced by it; but as this opinion has been drawn merely from the effects of the air of respiration, which is otherwise vitiated, it cannot be considered to stand on any sure basis. Hirt finds no symptoms of chronic poisoning by CO_2, even in trades where acute poisoning occasionally occurs.[4]

The presence of a very large amount of CO_2 in the air may lessen its elimination from the lungs, and thus retain the gas in the blood, and in time possibly produce serious alterations in nutrition.

(*b*) *Carbon Monoxide.*—Of the immense effect of carbon monoxide there is no doubt. Less than one-half per cent. has produced poisonous symptoms, and more than one per cent. is rapidly fatal to animals. It appears from Bernard's and from Lothär Meyer's observations[5] that the gas, volume for volume, completely replaces the oxygen in the blood, and cannot be again displaced by oxygen, so that the person dies asphyxiated; but Pokrowsky has shown[6] that it may gradually be converted into carbon dioxide, and be got rid of. It seems, in fact, as Hoppe-Seyler conjectured, to completely paralyse, so to speak, the red particles, so that they cannot any longer be the carriers of oxygen. The observations of Dr Kleber[7] show that, in addition to loss of consciousness and destruction of reflex action, it causes complete atony of the vessels, diminution of the vascular pressure, and slowness of circulation, and finally paralysis of the heart. A very rapid parenchymatous degeneration takes place in the heart and muscles gene-

[1] It is stated that Sir R. Christison employed air containing 20 per cent. of carbon dioxide as an anæsthetic. (Taylor's *Jurisprudence*, 1865, p. 713.)

[2] *Air and Rain*, p. 209 *et seq.*

[3] Quoted by Roth and Lex, *op. cit.*, p. 176.

[4] *Die Krankheiten der Arbeiter*, Erste Abtheilung, 2ter Theil, 1873.

[5] *De Sanguine Oxydo-carbonico Infecto*, 1858. Reviewed in Virchow's *Archiv*, Band xv. 309. See also Letheby, *Chemical News*, April 1862.

[6] Virchow's *Archiv*, Band xxx. p. 525 (1864).

[7] Virchow's *Archiv*, Band xxxii. p. 450 (1865).

rally, and in the liver, spleen, and kidneys. Hirt[1] says that at high temperatures (25° to 32° Cent. = 77° to 90° Fahr.) it produces convulsions, but not at low temperatures (8° to 12° Cent. = 46° to 54° Fahr.).

(*c*) *Hydrogen Sulphide.*—The evidence with regard to this gas is contradictory. While dogs and horses are affected by comparatively small quantities (1·26 and 4 volumes per 1000 volumes of air), and suffer from purging and rapid prostration, men can breathe a larger quantity. Parent-Duchâtelet inhaled an atmosphere containing 29 volumes per 1000 for some short time.[2]

When inhaled in smaller quantities, and more continuously, it has appeared in some cases harmless, in others hurtful. Thackrah, in his inquiries, could trace no bad effects. It is said that in the Bonnington chemical works, where the ammoniacal liquor from the Edinburgh gas-works is converted into sulphate and chloride of ammonium, the workmen are exposed to the fumes of ammonium and hydrogen sulphides to such an extent that coins are blackened; yet no special malady is known to result. The same observations have been made at the Britannia-metal works, where a superficial deposit of sulphide is decomposed with acids.

Hirt[3] has no doubt of the occurrence of chronic poison among men who work among large quantities of the gas. The symptoms are chiefly weakness, depression, perfect anorexia, slow pulse, furred tongue, mucous membrane of the mouth pale, as is also the face. Sometimes there is furunculoid eruption in different parts of the body. In some cases there are vertigo, headache, nausea, diarrhœa, emaciation, and head symptoms, "like a case of very slow running typhus." He notices differences of susceptibility, which is also sometimes increased with custom.

So large a quantity of SH_2 is given out from some of the salt marshes at Singapore that slips of paper moistened in acetate of lead are blackened in the open air; yet not only is no bad effect found to ensue, but Dr Little has even conjectured (on very disputable grounds, however) that the SH_2 may neutralise the marsh miasma.

On the other hand, some of the worst marshes in Italy are those in which SH_2 exists in large quantity in the air; and, in direct opposition to Little, it has been supposed that the highly poisonous action of the marsh gas is partly owing to the SH_2. Again, in the making of the Thames Tunnel, the men were exposed to SH_2, which was formed from the decomposition of iron pyrites: after a time they became feeble, lost their appetites, and finally passed into a state of great prostration and anæmia. Nor, so far as is known, was there anything to account for this except the presence of SH_2.[4]

Drs Josephson and Rawitz[5] have also investigated in mines effects produced apparently by SH_2; two forms of disease are produced—pure narcotic, and convulsive and tetanic symptoms. In the first case, the men became pale, the extremities got cold. There was headache, vertigo, a small weak pulse, sweating, and great loss of strength. On this spasms and tremblings sometimes followed, and even tetanus. The symptoms were acute, and not, as in the Thames Tunnel case, chronic. When these attacks occurred, the temperature was high and the air stagnant.

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[1] *Op. cit.*

[2] On dogs, Herbert Barker found a larger quantity necessary than that stated above, viz., 4·29 per 1000 is rapidly fatal, 2·06 per 1000 may be fatal, but 0·5 per 1000 may produce serious symptoms.

[3] *Op. cit.*

[4] Taylor's *Med. Jurisp.*, 1865, p. 727.

[5] Schmidt's *Jahr.*, Band cx. p. 334, and Band cxvii. p. 85.

The observations of Clemens, also, on the development of boils from the passage of SH_2 into the drinking water from the air, if not convincing, cannot be overlooked.

The symptoms produced by ammonium sulphide in dogs are said, by Herbert Barker,[1] to differ from those of SH_2. There is vomiting without purging, quickened pulse, and heat of skin, followed by coldness and rapid sinking. When hydrogen and ammonium sulphides, dissolved in water, are injected into the blood,[2] they, and especially SH_2 produce the same symptoms as the injection of non-corpuscular putrid fluids, viz., profuse diarrhœal evacuations, with sometimes marked choleraic symptoms and decided lowering of the temperature of the body, congestions of the lungs, liver, spleen, and kidneys, irritation of the spine, and opisthotonos. But, in this case a much larger quantity will be introduced than by inhalation through the lungs.

(*d*) *Carburetted Hydrogen.*—A large quantity of carburetted hydrogen can be breathed for a short time,—as much, perhaps, as 200 to 300 volumes per 1000. Above this amount it produces symptoms of poisoning, headache, vomiting, convulsions, stertor, dilated pupil, &c.

Breathed in small quantities, as it constantly is by some miners, it has not been shown to produce any bad effects ; but there, as in so many other cases, it is to be wished that a more careful examination of the point were made. Without producing any marked disease, it may yet act injuriously on the health. Hirt says that cases of chronic poisoning are not uncommon. Corfield has also noticed this.

(*e*) *Ammoniacal Vapours.*—An irritating effect on the conjunctiva seems to be the most marked effect of the presence of these vapours. There is no evidence showing any other effect on the health.[3]

(*f*) *Sulphur Dioxide.*—The bleachers in cotton and worsted manufactories, and storers of woollen articles, are exposed to this gas, the amount of which in the atmosphere is, however, unknown. The men suffer from bronchitis, and are frequently sallow and anæmic.

When SO_2 is evolved in the open air, and therefore at once largely diluted, as in copper smelting, it does not appear to produce any bad effects in men, and indeed persons living in volcanic countries have sometimes a notion that the fumes of SO_2 are good for the health ; Dr F. de Chaumont was told so by people in the neighbourhood of Vesuvius. When, however, it is washed down with rain, it affects herbage, and, through the herbage, cattle ; it is then said to cause affections of the bones, falling off of the hair, and emaciation.

(*g*) *Hydrochloric Acid Vapours* in large quantities are very irritating to the lungs ; when poured out into the air, as was formerly the case in the alkali manufactures, they are so diluted as apparently to produce no effect on men, but they completely destroy vegetation. In some processes for making steel, hydrochloric, sulphurous and nitrous acids, and chlorine are all given out, and cause bronchitis, pneumonia, and destruction of lung tissue, as well as eye diseases.[4]

(*h*) *Carbon Disulphide.*—In certain processes in the manufacture of vulcanised india-rubber a noxious gas is given off, supposed to be the vapour of carbon disulphide. It produces headache, giddiness, pains in the limbs,

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[1] *On Malaria and Miasmata*, p. 212.
[2] Weber, *Syd. Soc. Year-Book for* 1874, p. 227.
[3] See Schloesing, *Comptes Rendus*, 1875, vols. i. and ii.
[4] Jordan, *Canstatt's Jahresb. for* 1863, Band vii. p. 76.

formication, sleeplessness, nervous depression, and complete loss of appetite. Sometimes there is deafness, dyspnœa, cough, febrile attacks, and even amaurosis and paraplegia (Delpech). The effects seem due to a direct anæsthetic effect on the nervous tissue.

Sub-Section III.—Effects of Air Impure from several Substances always Co-Existing.

The examination of the effects of individual gases, however important, can never teach us the results which may be produced by breathing air rendered foul by a mixture of impurities. The composite effect may possibly be very different from what would have been anticipated from a knowledge of the action of the isolated substances.

(*a*) *Air rendered Impure by Respiration.*—The effect of the fœtid air containing organic matter, excess of water and CO_2, produced by respiration, is very marked upon many people; heaviness, headache, inertness, and in some cases nausea, are produced. From experiments on animals in which the carbon dioxide and watery vapour were removed, and organic matter alone left, Gavarret and Hammond have found that the organic matter is highly poisonous. Hammond found that a mouse died in forty-five minutes, and cases have been known in which the inhalation of such an atmosphere for three or four hours produced in men decided febrile symptoms (increased temperature, quickened pulse, furred tongue, loss of appetite, and thirst), for even twenty-four or forty-eight hours subsequently (Parkes).

When the air is rendered still more impure than this it is rapidly fatal, as in the cases of the Black Hole at Calcutta; of the prison in which 300 Austrian prisoners were put after the battle of Austerlitz (when 260 died very rapidly); and of the steamer "Londonderry." The poisonous agencies are probably the organic matters (and perhaps minute organisms), and the deficient oxygen, as the symptoms are not those of pure asphyxia. If the persons survive, a febrile condition is left behind, which lasts three or four days, or there are other evidences of affected nutrition, such as boils, &c.

When air more moderately vitiated by respiration is breathed for a longer period, and more continuously, its effects become complicated with those of other conditions. Usually a person who is compelled to breathe such an atmosphere is at the same time sedentary, and, perhaps, remains in a constrained position for several hours, or possibly is also under-fed or intemperate. But allowing the fullest effect to all other agencies, there is no doubt that the breathing the vitiated atmosphere of respiration has a most injurious effect on the health.[1] Persons soon become pale, and partially lose their appetite, and after a time decline in muscular strength and spirits.[2] The aëration and nutrition of the blood seem to be interfered with, and the general tone of the system falls below par. Of special diseases it appears pretty clear that pulmonary affections are more common.

Such persons do certainly appear to furnish a most undue percentage of phthisical cases, that is, of destructive lung-tissue disease of some kind. The production of phthisis from impure air (aided most potently, as it often is, by coincident conditions of want of exercise, want of good food, and

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[1] See, among a number of other instances, Guy's *Evidence before the Health of Towns Commission*, vol. i. p. 89 *et seq.*; and S. Smith, *ibid.*, p. 37 *et seq.*

[2] See Wilson's Observations on Prisoners, already cited, p. 141.

excessive work) is no new doctrine.[1] Baudelocque long ago asserted that impure air is the great cause of scrofula (phthisis), and that hereditary predisposition, syphilis, uncleanliness, want of clothing, bad food, cold and humid air, are by themselves non-effective. Carmichael, in his work on scrofula (1810), gave some most striking instances, where impure air, bad diet, and deficient exercise concurred together to produce a most formidable mortality from phthisis. In one instance, in the Dublin House of Industry, where scrofula was formerly so common as to be thought contagious, there were in one ward 60 feet long and 18 feet broad (height not given), 38 beds, each containing four children;[2] the atmosphere was so bad that in the morning the air of the ward was unendurable. In some of the schools examined by Carmichael the diet was excellent, and the only causes for the excessive phthisis were the foul air and the want of exercise. This was the case also in the house and school examined by Neil Arnott in 1832. Lepelletier[3] also recorded some good evidence. Professor Alison, of Edinburgh, and Sir James Clark, in his invaluable work, laid great stress on it. Neil Arnott, Toynbee, Guy, and others, brought forward some striking examples before the Health of Towns Commission.[4] Dr Henry MacCormac insisted with great cogency on this mode of origin of phthisis; and Dr Greenhow[5] also enumerated this cause as occupying a prominent place. Carnelley, Haldane, and Anderson show that in Dundee the ratio of phthisis and other disorders of a similar character increases with the crowding and foulness of the air; thus, taking houses of four rooms and upwards as 10, the other ratios are 3 rooms, 17; 2 rooms, 20; and 1 room, 23.

In prisons, the great mortality which formerly occurred from phthisis, as for example at Millbank (Baly), seemed to be owing to bad air, conjoined with inferior diet and moral depression.

Two Austrian prisons, in which the diet and mode of life were, it is believed, essentially the same, offer the following contrast:—

In the prison of Leopoldstadt, at Vienna, which was very badly ventilated, there died in the years 1834–47 378 prisoners out of 4280, or 88 per 1000, and of these no less than 220, or 51·4 per 1000, died from phthisis; there were no less than 42 cases of acute miliary tuberculosis.

In the well-ventilated House of Correction in the same city there were in five years (1850–54) 3037 prisoners, of whom 43 died, or 14 per 1000, and of these 24, or 7·9 per 1000, died of phthisis. The comparative length of sentences is not given, but no correction on this ground, if needed, could account for this discrepancy. The great prevalence of phthisis in some of the Indian jails appears to have been owing to the same cause, combined with insufficient diet.

The now well-known fact of the great prevalence of phthisis in most of the European armies (French, Prussian, Russian, Belgian, and English) can scarcely be accounted for in any other way than by supposing the vitiated atmosphere of the barrack-room to have been chiefly in fault. This is the

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[1] The following statistics (Ransome, *Sanitary Record*, vol. vi.) are instructive:—Death-rate from diseases of the respiratory organs for all England, 3·54 (1865–76); for Salford, 5·12; for registration district of Manchester, 6·10; for township of Manchester in 1874, 7·7: for Westmoreland (one of the healthiest counties), 2·27; for North Wales, 2·51. For diagrams showing the effects of aggregation of population on the ratio of respiratory diseases, see Dr F. de Chaumont's *Lectures on State Medicine*, table v. p. 48.

[2] This would give only $7\frac{2}{19}$ square feet per child, and if the ward was 12 feet high only 85 cubic feet. To ventilate such a space properly the air would have had to be changed about 30 times in the hour, a manifest impossibility.

[3] *Traité Complet de la Maladie Scrophuleuse.*

[4] *First Report*, 1844, vol. i. pp. 52, 60, 69, 79, &c.

[5] *Report on the Health of the People of England.*

conclusion to which the Sanitary Commissioners for the army came in their celebrated report. And if we must also attribute some influence to the pressure of ill-made accoutrements, and to the great prevalence of syphilis, still it can hardly be doubted that the chief cause of phthisis among soldiers has to be sought somewhere else, when we see that, with very different duties, a variable amount of syphilis, and altered diet, a great amount of phthisis has prevailed in the most varied stations of the army, and in the most beautiful climates; in Gibraltar, Malta, Ionia, Jamaica, Trinidad, Bermuda, &c. (see history of these stations), in all which places the only common condition was the vitiated atmosphere which our barrack system everywhere produced. And, as if to clench the argument, there has been of late years a most decided decline of phthisical cases in these stations, while the only circumstance which has notably changed in the time has been the condition of the air. So also the extraordinary amount of consumption which has prevailed among the men of the Royal and Merchant Navies, and which, in some men-of-war, has amounted to a veritable epidemic, is in all probability attributable to the faulty ventilation.[1]

The deaths from phthisis in the Royal Navy averaged (3 years) 2·6 per 1000 of strength, and the invaliding 3·9 per 1000. The amount of consumption and of all lung diseases was remarkably different in the different ships. These inferences received the strongest corroboration from the outbreak of a lung disease leading to the destruction of lung tissue in several of the ships on the Mediterranean station in 1860. Dr Bryson traced this clearly to contamination of the air, and noticed that in several cases the disease appeared to be propagated from person to person.[2] It may be inferred that pus cells were largely thrown off during coughing, and, floating through the air, were received into the lungs of other persons.

The production of phthisis in animals confirms this view. The case of the monkeys in the zoological gardens, narrated by Dr Arnott, is a striking instance. Cows in close stables frequently die from phthisis, or at any rate from a destructive lung disease (not apparently pleuro-pneumonia); while horses, who in the worst stables have more free air, and get a greater amount of exercise, are little subject to phthisis. But not only phthisis may reasonably be considered to have one of its modes of origin in the breathing an atmosphere contaminated by respiration, but other lung diseases, bronchitis and pneumonia, appear also to be more common in such circumstances. Both among seamen and civilians working in confined close rooms, who are otherwise so differently circumstanced, we find an excess of the acute lung affections. The only circumstance which is common to the two classes is the impure atmosphere. (Compare especially Gavin Milroy and Greenhow.) The favourite belief that these diseases are caused by transitions of temperature and exposure to weather has been carried too far.

In the South Afghanistan field force the artillery wintered at Kandahar (1880–81) in tents, and remained free from pneumonia, whilst the disease was prevalent among the infantry who were overcrowded in barracks. The 63rd, which was more crowded than the other corps, suffered most, having 30 cases in hospital at one time; one company, however, quartered in large airy rooms near the residence of the General commanding, had no case. On the 25th of March a part of the regiment was turned out into tents and the remainder were distributed in barracks, so that each man had a minimum of 600 cubic feet of space; from that time no more pneumonia occurred.[3]

[1] *Statistical Reports on the Health of the Navy*, and especially Gavin Milroy's pamphlet on the *Health of the Royal Navy*, 1862, pp. 44 and 54.

[2] *Trans. of the Epidem. Soc.*, vol. ii. p. 142.

[3] *Report* by Dept. Surg.-General Simpson.

In addition to a general impaired state of health, arising, probably, from faulty aëration of the blood, and to phthisis and other lung affections, which may reasonably be believed to have their origin in the constant breathing of air vitiated by the organic vapours and particles arising from the person, it has long been considered, and apparently quite correctly, that such an atmosphere causes a more rapid spread of several specific diseases, especially typhus exanthematicus, plague, smallpox, scarlet fever, and measles. This may arise in several ways : the specific poison may simply accumulate in the air so imperfectly changed, or it may grow in it (for though there may be an analogical argument against such a process, it has never been disproved, and it is evidently not impossible); or the vitiated atmosphere may simply render the body less resisting or more predisposed.[1]

(*b*) *Air rendered Impure by Exhalations from the Sick.*—The air of a sick ward, containing as it does an immense quantity of organic matter, is well known to be most injurious. The severity of many diseases is increased, and convalescence is greatly prolonged. This appears to hold true of all diseases, but especially of the febrile. At a certain point of impurity, erysipelas and hospital gangrene appear. The occurrence of either disease is, in fact, a condemnation of the sanitary condition of the ward. It has been asserted that hospital gangrene is a precursor of exanthematic typhus,[2] but probably the introduction at a particular time of the specific poison of typhus was a mere coincidence. But, doubtless, the same foul state of the air which aids the spread of the one disease would aid also that of the other.

When hospital gangrene has appeared, it is sometimes extremely difficult to get rid of it. Hammond[3] states that in a ward of the New York City Hospital, where hospital gangrene had appeared, removal of the furniture and patients did not prevent fresh patients being attacked. Closing the ward for some time and white-washing had no effect. The plastering was then removed, and fresh plaster applied, but still cases recurred. At last the entire walls were taken down and rebuilt, and then no more cases occurred.

It is now well known that by the freest ventilation, *i.e.*, by treating men in tents or in the open air, hospital gangrene can be entirely avoided.[4] The occurrence of hospital gangrene in a tent is a matter of the rarest occurrence.

(*c*) *Air rendered Impure by Combustion.*—Of the products of combustion which pass into the general atmosphere, the carbon dioxide and monoxide are so largely and speedily diluted that it is not likely they can have any influence on health. The particles of carbon and tarry matter, and the sulphur dioxide, must be the active agents if any injury results. It has been supposed that the molecular carbon and the sulphur dioxide, instead of being injurious, may even be useful as disinfectants, and we might *a priori* conclude that to a certain extent they must so act; but certainly there is no evidence that the smoky air of our cities, or of our colliery districts, is freer from the poisons of the chief specific diseases than the air of other places. It has been supposed, indeed, that the air of large cities is particularly antagonistic to malaria, and it is true that they have less diphtheria, in this country, than the rural districts, but there are probably other

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[1] For Dr Lawson's views on the effects of clothing, see Chapter on PREVENTION OF DISEASE.
[2] See Guillemin, *Recueil de Mémoires de Méd. Ch.* and *Pharm. Militaires*, No. 159, 1874.
[3] *On Hygiene*, p. 172.
[4] See Chapter on HOSPITALS, and Professor Jüngken's Address on Pyæmia, in the *Sydenham Society Year-Book for* 1862, p. 213; and Report on Hygiene, by Dr Parkes, in the *Army Medical Report for* 1862 (vol. iv.).

causes acting in those cases. The solid particles of carbon, and the sulphur dioxide, may, on the other hand, have injurious effects. It is not right to ignore the mechanical effect of the fine powder of coal so constantly drawn into the lungs, and even the possibility of irritation of the lungs from sulphur dioxide. Certain it is, that persons with bronchitis and emphysema often feel at once the entrance into the London atmosphere; and individual experience will probably lead to the opinion that such an atmosphere has some effect in originating attacks of bronchitis and in delaying recovery. But statistical evidence of the effect of smoky town atmospheres in producing lung affections on a large scale cannot be given, so many are the other conditions which complicate the problem. There is, however, no doubt of the evil effect of the London atmosphere during dense fogs: witness the effect upon the animals at the cattle show at Islington in December 1873, and the increased mortality from lung diseases during foggy weather.

The effect of breathing the products of combustion, of gas especially, is more easily determined. In proportion to the amount of contamination of the air, many persons at once suffer from headache, heaviness, and oppression.

Bronchitic affections are frequently produced, which are often attributed to the change from the hot room to the cold air, but are really probably owing to the influence of the impure air of the room on the lungs.

The effects of constantly inhaling the products of gas combustion may be seen in the case of workmen whose shops are dark, and who are compelled to burn gas during a large part of the day; the pallor, or even anæmia and general want of tone, which such men show is owing to the constant inhalation of an atmosphere so impure.

(d) Air rendered Impure by the Gas and Effluvia from Sewers and House Drains.—Cases of asphyxia from hydrogen sulphide, ammonium sulphide, carbon dioxide, and nitrogen (or possibly rapid poisoning from organic vapours), occasionally occur both in sewers and from the opening of old cesspools. In a case at Clapham, the clearing out of a privy produced in twenty-three children violent vomiting and purging, headache, and great prostration, and convulsive twitchings of the muscles. Two died in twenty-four hours.[1]

These are instances of mephitic poisoning in an intense degree; but when men have breathed the air of a newly opened drain in much smaller amounts, marked effects are sometimes produced; languor and loss of appetite are followed by vomiting, diarrhœa, colic, and prostration. The effluvia which have produced these symptoms are usually those arising from a drain which has been blocked for some time. When the air of sewers penetrates into houses, and especially into the bed-rooms, it certainly causes a greatly impaired state of health, especially in children. They lose appetite, become pale and languid, and suffer from diarrhœa; older persons suffer from headaches, malaise, and feverishness; there is often some degree of anæmia, and it is clear that the process of aëration of the blood is not perfectly carried on.[2]

In some cases decided febrile attacks lasting three or four days, and attended with great headache and anorexia, have been known. Houses into which there has been a continued escape of sewer air have been so

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[1] *Health of Towns Report*, vol. i. p. 139.
[2] *Health of Towns Report.* See especially the evidence of Rigby, vol. i. p. 151, and of Aldis, vol. i. p. 115.

notoriously unhealthy that no persons would live in them and this has not been only from the prevalence of fever, but from other diseases. Dr Marston (Medical Staff), in his excellent paper on the Fever of Malta,[1] tells us that when enteric fever broke out at the Fort of Lascaris, from the opening of a drain, other affections were simultaneously developed, viz., "diarrhœa, dysentery, slight pyrexial disorders, and diseases of the primary assimilative organs." A close examination and analysis of the affections produced by the inhalation of sewer air would probably much enlarge this list; and the class of affections resulting from this cause, to which it may be difficult to assign a nosological name, will be found to be essentially connected with derangement of the digestive rather than with the pulmonary system.

Dr Herbert Barker[2] attempted to submit this question to experiment by conducting the air of a cesspool into a box. where animals were confined. The analysis of the air showed the presence of CO_2, hydrogen sulphide, and ammonium sulphide. The reaction of the gas was usually neutral, sometimes alkaline. The gas was sometimes offensive, so that organic vapours were probably present; but no analysis appears to have been made on this point. Three dogs and a mouse were experimented on; the latter was let down over the cesspool, and died on the fifth day. The three dogs were confined in the box; they all suffered from vomiting, purging, and a febrile condition, which, Dr Barker says, "resembled the milder forms of continued fever common to the dirty and ill-ventilated homes of the lower classes of the community." But the effects required some time and much gas for their production. Dr Barker attributes the results, not to the organic matter, but to the mixture of the three gases, and specially to the latter two.

The effect on the men who work in sewers which are not blocked, or temporarily impure from exceptional disengagement of hydrogen sulphide from any cause,[3] has been subject to much debate. The air in many sewers in London is not very impure; the analyses of Letheby and Miller have shown that generally the amount of CO_2 is very little in excess of that in the external air, and that there is hardly a trace of hydrogen sulphide or of fœtid organic effluvia. The air in the house drains is often, in fact, more impure than that of the main sewers. This is the case also in other places, and is to be accounted for by the numerous openings in the sewers, from the porosity of the walls, from the continual ventilation produced by the air being drawn into houses, and from the amount of water in the sewers being often so great, and its flow so rapid, as to materially lessen the chances of generation of gas. The evidence is, on the whole, opposed to the view that sewer-men suffer in health in consequence of their occupation. Thackrah stated[4] that sewer-men were not subject to any disease (apart from asphyxia) and were not short-lived. He cited no evidence. Parent-Duchâtelet[5] came, on the whole, to the same conclusion as regards the sewer-men of Paris in 1836. He said that there were some men so

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[1] *Army Med. Report for* 1861, p. 486. [2] *Malaria and Miasmata*, 1863, p. 176 *et seq.*

[3] Fatal cases have occurred both in London and Liverpool sewers from the rapid evolution of SH_2, either from gas liquid, or, in Liverpool, from the action of acids passing into the sewers, and meeting with sulphide of calcium in the refuse derived from alkali manufactories.

[4] *The Effects of Arts, Trades, and Professions on Health*, 1832, p. 118.

[5] *Hygiène Publique*, vol. i. p. 247 (1836). The conclusions of Parent-Duchâtelet are not entirely justified by his evidence. The number of men he examined was small, and many of them had been employed for a short time only in the sewers; it also appeared that a considerable number had actually suffered from bilious and cerebral affections. (See the former editions of this work.)

affected by the air of sewers that they could never work in them; but those who could remain suffered only from a little ophthalmia, lumbago, and perhaps sciatica. They considered otherwise their occupation not only innocent, but as favourable to health. The only fact adverse to this seemed to be that the air of the sewer greatly aggravated venereal disease, and those who persisted in working with disease on them inevitably perished. The working in deep, old sewage matter produced an eruption on the parts bathed by the mud, which resembled itch sometimes, or was phlyctenoid in character.

A more recent inquiry conducted into the health of the sewer-men in London did not detect any excess of disease among them,[1] and in Liverpool also the sewer-men are said to have good health. The workmen employed at the various sewage outfalls, who, though not in the sewers, breathe the effluvia arising from the settling tanks, do not find it an unhealthy occupation.

It does not, appear, therefore, that at present the workmen connected with fairly ventilated sewers show any excess of disease; at the same time, it must be allowed that the inquiry has not been very rigorously prosecuted, and that the length of time the men work in sewers, their average yearly mortality, discharge from sickness, loss of time from sickness, and the effect produced on their expectation of life, have not been perfectly determined.

The air of sewers passing into houses aggravates most decidedly the severity of all the exanthemata—erysipelas, hospital gangrene, and puerperal fever (Rigby); and it has probably an injurious effect on all diseases. That pneumonia may be produced is shown by the case of the East Sheen School.

Two special diseases have been supposed to arise from the air of sewers and fæcal emanations, viz., *diarrhœa* and *enteric fever.*

With regard to the production of diarrhœa from fæcal emanations, it would seem that the autumnal diarrhœa of this country is intimately connected with temperature,[2] and usually commences when the thermometer is persistently above 60°, and when there is, at the time, a scarcity of rainfall. It is worst in the badly-sewered districts, and is least in well-drained districts, and in wet years. It has been checked in London by a heavy fall of rain. All those points seem to connect it with fæcal emanations reaching a certain rapidity of evolution in consequence of high temperature, deficient rain, and perhaps relative dryness of the atmosphere. At the same time, there is a connection between this disease and impure water. It may own a double origin, and in a dry season both causes may be in operation.

That enteric fever may arise from the effluvia from sewers is a doctrine very generally admitted in this country, and is supported by strong evidence. There are several cases on record in which this fever has constantly prevailed in houses exposed to sewage emanations, either from bad sewers or from want of them, and in which proper sewerage has completely removed the fever.[3] Many of these cases occurred before the water-carriage

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[1] In reference to this point, however, a writer in the *Lancet* (April 1872) very justly pointed out that the statistics are very imperfect in taking no notice of men who have been discharged or who have died.

[2] Ransome and Vernon, *Influence of Atmosph. Changes on Dis.*, p. 3.

[3] In *Health of Towns Reports and Evidence*, Sir J. Simon's *Reports*, Dr Letheby's *Reports*, Sir H. Acland's *Reports on Fevers in Agricultural Districts*, and the *Reports of the Medical Officer to the Privy Council*, will be found abundant evidence in support of this assertion. Many provincial towns in England could give similar evidence, as Norwich. (See Dr Richardson's Report, *Medical Times and Gazette*, Jan. 1862.) The case of Calstock, in Devonshire, may be also noted. It used to be also liable to outbreaks of enteric fever, but after the drainage of the place the fever disappeared. (Bristowe, in *Trans. of Epid. Soc.*, vol. i. p. 396.) Murchison not only adopted this view, but even proposed to give the term "pythogenic fever" to enteric.

of enteric fever was recognised, but yet the connection between the sewage emanation and the fever seems undoubted.

This evidence is supported by cases in which the opening of a drain has given rise to decided enteric fever,[1] as well as to a very fatal disease (probably severe enteric) in which coma is a marked symptom. So also in some instances (Windsor and Worthing)[2] the spread of enteric fever has evidently been owing to the conveyance of effluvia into houses by the agency of unventilated sewers. In a case from private information, an outbreak of enteric fever in a training-school was localised in certain parts of the school (whereas the drinking water was common to all), and was traced to imperfection of traps in those parts of the house which were affected. In this case the drains led down to a large tank at some distance, and at a much lower level, and the smell of the effluvia was so slight that at first it was not believed that the drains could be out of order. A very good case is given by Surgeon Page,[3] late 6th Dragoons, in his description of an outbreak of enteric fever at Newbridge, following discontinuance of the use (on account of repairs) of a ventilating shaft for the sewers. Sewer-air got into the barracks, and several cases (some fatal) of enteric fever occurred. Other possible causes were carefully inquired into and eliminated.[4] These two classes of facts seem decidedly to show a causal connection between the effluvia from sewers and enteric fever, and they are supported by the statistical evidence which proves that the prevalence of enteric fever stands in a close relation to the imperfection with which sewage matters are removed. The army statistics give excellent instances of this, and the evidence produced by Dr Buchanan of the prevalence of enteric fever before and after sewerage of a town is to the same effect.[5]

The persistent existence of enteric fever at Eastney barracks, Portsmouth, appears to have been traceable to sewer air driven back into the quarters by the tide, there being no traps or ventilating openings. Since October 1878, when the drains were put in better order, and better flushed and ventilated, there has been no fever.[6]

German writers have lately commented much upon the view that there is a connection between sewer air and enteric fever, and reference may be specially made to the papers of Soyka, Renk, A. de Rozsahegyi, and Lissauer.[7] Their contention is that enteric fever is not due to the influence of sewer air, because it is rare that such air gets into houses; and experiments are cited to prove this. It is, however, admitted and demonstrated by Soyka, in the tables which he gives, that a similar improvement in the health of towns has followed the introduction of proper drainage in the cities of Germany as has been observed in this country. This is attributed to the cleansing of the soil and the atmosphere by the removal of the sewage matter, although they still insist upon the essentially local or *topical* character of the disease. Von Nägeli[8] positively denies the possibility of

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[1] For references to illustrative cases, see 5th edition of this work, p. 128, note.

[2] *Ninth Report of Medical Officer to the Privy Council*, p. 44.

[3] *Army Med. Report*, vol. xv. p. 301.

[4] An outbreak at Kinsale, apparently due to sewer effluvia, is narrated by Surgeon-Major Wallace, *Army Med. Reports*, vol. xvii. p. 55. The inquiry seems to have been very carefully made.

[5] *Ninth Report of Medical Officer to the Privy Council*, p. 44. In twenty-one English towns the average reduction of enteric mortality after sewerage was 45·4 per cent. In many of the towns an improved water supply was introduced at the same time, but the purification of the air by sewerage and cleanliness has, it is believed by Buchanan, "been most uniformly followed by a fall in the prevalence of typhoid."

[6] See "Report on Hygiene," *A.M.D. Reports*, vol. xx. p. 222.

[7] *Deutsche Vierteljahrschrift für öffentliche Gesundheitspflege*, 1881.

[8] *Die Niederen Pilze*, 1877, p. 215 *et seq.*

specific disease being conveyed through emanations from drains or cess-pools.

Although it seems difficult not to admit that the effluvia from the sewers will produce enteric fever, there are yet some remarkable facts which can be cited on the other side.

It has been denied by Parent-Duchâtelet and by Guy [1] that enteric fever is more common among sewer-men than others, and later inquiries among the sewer-men of London seem to bear out the assertion. But, as already stated, the air of London sewers is really tolerably pure; and some of the men may be protected by previous attacks, for enteric fever is a most common disease among the poorer children in London. Murchison [2] and Peacock also stated, on the other side, that enteric fever was not uncommon among sewer-men. This argument, therefore, is not of great weight.

The evidence is very strong that the men employed at the sewage tanks and on the sewage farms, and their families, do not show an unusual amount of enteric fever; nor do the persons living in adjacent houses. Now, if sewage emanations can cause enteric fever, it might be expected that we should by this time have had plenty of evidence of this special effect. Again, in our rural villages, and in many farm houses, the excreta of men and animals literally cover the ground, and it might have been anticipated that enteric fever would never be absent. If this is the case in this country, it is still more so in China, where the excreta are so carefully stored and applied to land. In a report made by various medical officers, the writers state that, in Chinese villages surrounded with excreta, where the contamination of the air by fæcal emanations is very great, there is no enteric fever. And as enteric is well known in other parts of China, the absence is not owing to any peculiarity of climate preventing the appearance of the fever.[3]

We have, then, counter-facts which must be allowed to be of considerable weight. Any explanation, to be satisfactory, must not ignore one set of facts, but must impartially include both.

The possibility that the adult persons submitted to sewage emanations may have had enteric fever in early life, and are therefore insusceptible, may explain some cases of escape, even when fæcal emanations are constantly breathed. But it would be impossible to extend this argument to the cases of immunity in children, unless we suppose that enteric fever in children is constantly overlooked, and is as common as measles, which seems unlikely.

It has been supposed that there is an essential difference when animal and vegetable substances are decomposing in covered places and in the open air.[4] It is evident that the physical conditions will be widely different in the two cases. In underground channels there is greater mean temperature, more moisture, and a more stagnant atmosphere. In the open air, while there may be heat from the sun's rays, this may restrain putrefaction; while the coldness of the nights and the much greater movement and dryness of the air may hinder the formation or lessen the chance of reception of any fever-causing substance developed during the putrefaction. At first sight, there appears to be much in favour of this view, and it would explain

[1] *Journal of the Statistical Society*, 1848. [2] *On Fevers*, p. 453.

[3] See Reports by Drs Miller and Manson, for Shanghai and Amoy, in the *Customs Gazette of China*, July-Sept. 1871.

[4] This is the view taken in the *Second Report of the State Board of Health of Massachusetts*. From an inquiry in most of the large cities of that state, the conclusion is drawn that it is putrefaction of animal and vegetable substances, *under cover*, which gives enteric fever.

the greater chance there appears to be of effluvia coming from sewers causing enteric fever than when the effluvia came from excreta in the open air. But it does not meet two undoubted facts, viz., that there are cases in which sewer air is breathed without causing enteric fever, and the occasional severe outbreaks of it in villages without sewers, and where there is no putrefaction under cover.

That the importation of enteric fever into places previously free for years is followed by outbreak [1] is quite certain. In many of these cases, as in the excellent instance at Steyning, recorded by Whitely,[2] all the conditions of accumulated sewage, &c., which are supposed to produce enteric fever, were present for years, and yet no fever resulted. Then a patient came from a distance with enteric fever, and the disease spread through the village, either through the medium of the water (as is perhaps most common) or through the air. These instances are so numerous that the entrance of a fresh agent must be admitted, and if so, the series of events becomes quite intelligible.

The doctrine that a specific cause is necessary for the production of enteric fever; that this cause is present in the intestinal discharges, and that sewers and fæcal effluvia, and fæcal impregnation of water, are thereby the channels by which this specific cause reaches the body of a susceptible person (*i.e.*, of a person who has not previously had the disease), will be found to explain almost all the events which have been recorded in connection with the origin of enteric fever.

There are, however, still some difficulties. There are instances in which enteric fever arises from sewer air without any possibility of tracing the entrance of a person with the disease.[3] Sometimes, as in the case of an isolated house in the country, it seems most difficult to believe that any such entrance could have taken place. It must, however, be remembered that the carriage of the "contagion" takes place in so many ways that it is impossible always to trace it. In the case of enteric fever, the stools are not only infectious during the height of the disease, but probably during the early period of recovery; and the disease itself is also often so slight that persons move about, and believe they have only an attack of diarrhœa. Again, the frequent journeying from place to place exposes all persons to a greater chance of inhaling the enteric effluvia, and the real source of the disease may be far removed from the place which is actually suspected.

There are, again, cases in which enteric fever occurs in persons who have not been exposed apparently to sewer air, or fæcal emanations, or to the charge of any enteric contagion. Dr Gordon Hardie has recorded two cases of this kind in soldiers attacked during imprisonment. Such cases can only be explained either by supposing an incubative period of extraordinary length, or an origin apart altogether either from fæcal emanations or a prior case of the disease.

Admitting, however, that there are still difficulties to be explained by future observation, it seems clear that the theory of a specific cause reproducing itself in the intestines and contained in the discharges, and naturally, therefore, connected more or less closely with excreta and sewers, and sometimes with drinking water, is that which best meets the facts which have been most faithfully reported in outbreaks of enteric fever. The evidence

[1] The cases recorded sixty years ago by Bretonneau have been confirmed by many observations since.

[2] *From the Report of the Medical Officer to the Privy Council*, p. 43.

[3] Ranke admits the possibility of spontaneous origin of enteric fever, but thinks it spreads more frequently through air than any other way.

of the carriage of a cause of this kind in water strongly supports this view.

(*e*) *Emanations from Fæcal Matter thrown on the Ground.*—Owing, doubtless, to the rapid movement of the air, there is no doubt that the excreta of men and animals thrown on the ground and exposed to the open air are less hurtful than sewer air, and probably in proportion to the dilution.

When there are accumulations in close courts, small back-yards, &c., the same effects are produced as by sewer air, and many instances are recorded in the *Health of Towns Report.* When fæcal matters are used for manure, and are therefore speedily mixed with earth, they seldom produce bad effects. Owing, doubtless, to the great deodorising and absorbing powers of earth, effluvia soon cease to be given off. An instance is, however, on record in which two cases of enteric fever were supposed to arise from the manuring of an adjacent field. Dr Clouston has also shown by evidence, which seems very strong, that dysentery was produced in an asylum by the exhalations from sewage, which was spread over the ground (a stiff brick clay subsoil) about 300 yards from the asylum. The case seems a very convincing one, as the possibility of the action of other causes (impure water, bad food, &c.) was excluded. This is a point on which more evidence is desirable. It is stated in some works that disease is frequently produced by the manuring of the ground, but there seems to be no satisfactory evidence of this. On the other hand, Dr A. Carpenter showed, from the history of Beddington sewage farm, that no harm to the neighbourhood had accrued from the irrigation with the Croydon sewage during twenty years,[1] and subsequent experience has only confirmed his statements. It has been said that if the sewage matter can be applied while perfectly fresh to the ground, no harm results; but if decomposition has fully set in, it is not so completely deodorised by the ground.[2] In China, where fæcal matter is so constantly applied in agriculture, the air is often filled with very pungent effluvia, yet no bad effect is produced.[3]

(*f*) *Emanation from Streams polluted by Fæcal Matter.*—The evidence on this point is contradictory. Parent-Duchâtelet, in 1822,[4] investigated the effect produced on the health of the inhabitants of the Faubourg St Marceau, in Paris, by the almost insupportable effluvia arising from the Rivière de Bièvre, which received a large portion of the sewage of the quarter. He asserts that the health was not at all damaged, though he admits that there is truth in the old tradition at the Hôtel Dieu, that the cases from St Marceau were more severe than from any other place.

Dr M'William found that the emanations from the Thames in 1859–60 had no deleterious effect on the health of the Custom-House men employed on the river. The amount of diarrhœa was even below the average.

Sir R. Rawlinson states[5] that a careful house-to-house visitation had been made in some of the worst districts of Lancashire (in Manchester, on the banks of the Medlock, for instance) without finding any great excess of disease.

On the other hand, in the reports of Sir H. De la Beche and Dr Lyon Playfair[6] is some strong evidence that the general health of the people

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[1] The Utilisation of Town Sewage by Surface Irrigation, by A. Carpenter, M.D., *Trans. Internat. Medical Congress*, London, 1881, vol. iv. [2] See chapter on SEWAGE.

[3] Dr A. Jamieson's "Report on the Health of Shanghai for the half-year ending September 1870," *China Customs Gazette* for 1870, Shanghai, 1871. [4] *Hygiène Publique*, p. 98.

[5] *Report of Committee on Sewage*, 1864, p. 174, Question 3997.

[6] *Second Report of the Health of Towns Commission*, pp. 261 and 347.

suffered from the emanations of the putrid streams of the Frome and the tributaries of the Irk and Medlock; that they were pale, in many cases dyspeptic; that fevers (enteric) prevailed on the banks is asserted by some observers, but rather doubted by others; but none seem to have any doubt that the fevers when they occurred were much worse. Cholera in Manchester was severe along the banks of some of these streams, but that might have been from the water being drunk. In 1858, also, Dr Ord[1] observed that a large number of the men employed on the Thames were affected by the effluvia, the symptoms being languor and depression, followed by nausea and headache, aching of the eyeballs, and redness and swelling of the throat. Diarrhœa was rare. In 1859 these symptoms were not observed, though the state of the river was worse. Were they then really caused by the effluvia in 1858?

It is very likely that the discrepancy of evidence may arise from the amount of water which dilutes the fæcal matter being much greater in some cases than others. In the case of the Thames, the dilution was after all very great, and this was the case, in part at any rate, in the Bièvre, as the stream was in some places 6 and 7 feet deep. The evaporation from such a body of water, however offensive it may be, must be a very different thing from the effluvia coming off from the masses of organic matter laid bare by the almost complete drying up of streams into which quantities of fæcal matter are discharged. When sewage matter is poured into the sea, and washed back by the tide, it becomes a source of danger.

It was remarkable in the evidence given before the Royal Commission on Metropolitan Sewage Discharge, 1882–84, how little direct proof of specific disease, due to the pollution of the Thames, was obtained, although there was no doubt about the production of nausea and diarrhœa, and other minor evils. Indeed, the Commissioners themselves had good proof of this, for, after a trip of inspection from Woolwich to Greenhithe in July 1884, three of them and their clerk were seized with griping pains and smart diarrhœa the same night, caused apparently by the offensive state of the river.[2]

(*g*) *Effect of Manure Manufactories.*—The manure manufactories at present existing in this country do not appear to produce any bad effects. They are generally at some little distance from towns, and the effluvia are soon diluted. The Secretary of the Hyde Manure Company stated that while the works were in operation no bad effects were observed. But if situated in towns they are nuisances, and may be hurtful. In 1847 evidence was given to show that a manure manufactory situated in Spitalfields, and about 100 feet from the workhouse, caused bad diarrhœa whenever the wind blew in that direction, and 12 cases of "spontaneous gangrene" (!) which had appeared among children were attributed to it. The cases of disease in the workhouse infirmary also acquired, it is said, a malignant and intractable character.[3] In France the workmen engaged in the making of "poudrette" do not in any way suffer, except from slight ophthalmia.[4] Parent-Duchâtelet[5] (on very slight evidence indeed) thought the emanations

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[1] *Trans. Social Science Association*, 1859, p. 571.

[2] See Appendix to *Second Report*, &c., *op. cit.*

[3] *Medical Gazette*, December 1847.

[4] Parent-Duchâtelet; Patissier. See also Tardieu, *Dict. d'Hygiène*, t. iv. p. 453. Tardieu, in 1862, writes—"We do not hesitate to affirm that the exhalations from these manufactories (*voiries*) exercise no injurious action either on man or vegetation." But it must be remembered that these places are excellently conducted; ventilation is good, and the fæcal matter is soon subjected to processes which prevent its decomposition.

[5] *Hyg. Publique*, t. ii. p. 276.

were even beneficial in some diseases, and Tardieu seems inclined to support this opinion. When the poudrette is decomposing, and large quantities are brought into small spaces, as on board ship, serious consequences may certainly result. Parent-Duchâtelet records two cases of outbreaks on board ships carrying poudrette which fermented on the voyage; one vessel, the "Arthur," lost half her crew (number not known), and the rest were in a state of deplorable health; the men who unloaded the cargo were also affected. The symptoms are not recorded; but, in a smaller vessel, where all on board (5) were similarly affected, the disease put on the appearance of "an adynamic fever." There was intense pain of the head and of all the limbs, vomiting, great prostration, and in two cases severe diarrhœa. These symptoms are very similar to those already mentioned as produced in the children at Clapham by the opening of a privy. In bone manure factories it has been shown that arsenic is given off in the fumes in considerable quantity, arising from the use of impure sulphuric acid.[1]

(*h*) *The Air of Graveyards.*—There is some evidence that the disturbance of even ancient places of sepulture may give rise to disease. Vicq d'Azyr refers to an epidemic in Auvergne caused by the opening of an old cemetery; the removal of the old burial-place of a convent in Paris produced illness in the inhabitants of the adjoining houses.[2] In India, the cantonment at Sukkur was placed on an ancient Mussulman burial-ground, and the station was most unhealthy,[3] especially from fevers.

The effect of effluvia from comparatively recent putrefying human bodies has been observed by many writers. Rammazzini[4] states that sextons entering places where there are putrefying corpses are subject to malignant fevers, asphyxia, and suffocating catarrhs; Fourcroy remarks that there are a thousand instances of the pernicious effects of cadaveric exhalations; and Tardieu[5] has collected a very considerable number of cases, not only of asphyxia, but of several febrile affections produced by exhumations and disturbance of bodies. Mr Chadwick,[6] and the General Board of Health,[7] also summed up evidence, which showed that in churchyards thickly crowded with dead, vapours were given off which, if not productive of any specific disease, yet increased the amount both of sickness and mortality. In some instances, this might have been from contamination of the drinking water; but in other cases, as in the houses bordering the old city graveyards, where the water was supplied by public companies, the air also must have been in fault. In the houses which closely bordered the old city yards, which were crowded with bodies, cholera was very fatal in 1849,[8] and, according to some practitioners, no cases recovered. All other diseases in these localities were said to have assumed a very violent and unfavourable type. Hirt says, on the other hand, that when grave-diggers are protected from the acute effects of carbon dioxide, their calling is not unhealthy; their death-rate he gives at 17 per 1000, and their mean duration of life at 58–60 years. This, however, is in Germany, where, as he admits, there is less crowding of graveyards than in England or France. Nägeli, arguing probably from similar data, thinks that graveyards may exist in the midst of towns without danger to health, provided precautions be taken with

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1 *On the Presence of Arsenic in the Vapours of Bone Manure*, by James Adams, M.D., 1876, &c.

2 Tardieu, *Dict. d'Hygiène*, i. p. 517.

3 Norman Chevers, *European Soldiers in India*, p. 404.

4 *Maladies des Artizans*, p. 71.

5 *Dict. d'Hygiène*, 1862, t. iii. p. 463 *et seq.*

6 *Report on Interments in Towns.*

7 *Report on Extramural Sepulture*, 1850.

8 S. Smith and Sutherland's *Reports on Extramural Interment*, p. 12. See also Sutherland's *Report on Cholera*, 1850, p. 27.

reference to the drainage and ventilation of the soil. Some writers have attributed the origin of *Dengue* to decomposing dead bodies insufficiently buried (Christie).

(*i*) *Effluvia from Decomposing Animals.*—On this point there is some discrepancy of evidence.

In 1810 Deyeux, Parmentier, and Pariset gave evidence to show that the workmen in knackeries are in no way injured. Parent-Duchâtelet, from his examination of the health of the men employed at the knackery and slaughter-house at Montfaucon, came also to the conclusion that their health was not affected. It should be mentioned that this knackery is remarkably well placed for ventilation, and is excellently conducted; putrid remains, in the proper sense of the word, do not now exist in any knackery in or near Paris; the workmen are well paid and well fed, and are therefore prepared to bear the effect of any injurious effluvia. It has been stated, however, that in the Hôtel Dieu the patients used to suffer when the wind, loaded with effluvia, blew from Montfaucon (Henry Bennet). Tardieu, from a late re-examination of the question, confirms Parent's conclusions,[1] except as regards glanders and malignant pustule, touching which Parent-Duchâtelet's evidence was as usual negative. Tardieu,[2] however, states that many examples occur in the French knackeries of the transmission of these diseases, though glanders and farey are less frequently caught in knackeries than in stables. No analysis has yet been made of the air of knackeries.

Parent-Duchâtelet[3] is also often quoted as having proved that the exposure of the remains of 4000 horses, killed in the battle of Paris in 1814, produced no bad effects. These horses were killed on the 30th March, and were burnt on the 10th and 12th April. They gave out "une odeur infecte," which produced no bad results on those who collected the bodies. Parent-Duchâtelet inquired particularly whether typhus was produced by the effluvium, and proved that it was not,—a conclusion conformable to our present doctrine. He did not, however, do more than examine the registers of deaths of the three years before, during, and after the battle, and found no evidence for increased mortality. The utmost this observation shows is, that no typhus was produced, and that the amount of decomposition, caused by eleven days of hot weather, did not affect those concerned in collecting and burning the bodies.

On the other hand, the experience of many campaigns, where soldiers have been exposed to the products of an advanced putrefaction of horses, shows that there is a decided influence on health. Pringle especially noticed this; and in many subsequent campaigns this condition has been one of the causes of insalubrity. Diarrhœa and dysentery are the principal diseases; but all affections are increased in severity. At the siege of Sebastopol, where, in the French camp, a great number of bodies of horses lay putrefying on the ground, Reynal[4] describes the effect as disastrous, and even conjectures that the spread of typhus was connected with this condition, though this is unlikely.

(*k*) *Air of Brickfields and Cement Works.*—The peculiar smell of brickfields cannot be owing to carbon dioxide or monoxide, or to hydrogen sulphide or sulphur dioxide (the gases evolved from the kilns); but its exact cause is not known. The air, at its exit from the chimneys of furnaces and kilns, is rapidly fatal; but so rapid is its ascension, dilution, and

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[1] *Dict. d'Hygiène*, t. iv. p. 468.
[2] *Op. cit.*, t. iv. p. 468.
[3] *Dict. d'Hygiène*, t. i. p. 47.
[4] Tardieu, *Dict. d'Hygiène*, t. ii. p. 121.

diffusion, that at a little distance it is respirable. In almost all the actions against the owners of brickfields nothing more than a nuisance has been established, and this not in the legal sense. The smoke and gases from cement works, however, destroy neighbouring vegetation. The smell can be perceived for several hundred yards.[1] In the north of France it is ordered that no kilns shall be within 50 metres (54½ yards) of a public road; and the kilns are lighted only at night.

(*l*) *Air of Tallow-Makers, Boneburners, &c.*—In many trades of this kind large quantities of very disagreeable animal vapours are produced, which spread for a long distance, and are most disagreeable. Although a nuisance, it is difficult to bring forward positive evidence of insalubrity. But the odour is so bad that in France rules are in force to oblige the vapours to be condensed or consumed,[2] and if in the process any water is contaminated with fatty acids, it is neutralised with lime. M. Foucon has figured an apparatus which completely burns the animal vapours.[3]

(*m*) *Air of Marshes.*—It seems scarcely necessary to allude to this point, except to notice that, in addition to paroxysmal fevers, it has been supposed that serous diarrhœa (a sort of dysenteria incruenta) and true bloody dysentery, are produced by malaria. Also that there is perhaps some connection between malaria and liver abscess (?). The breathing of marsh air also may produce an imperfect condition of nutrition, in which enlarged spleen plays a prominent part, and the mean duration of life is shortened.

(*n*) *Unknown Conditions of the Atmosphere.*—Occasionally, outbreaks of disease occur from impurities of the atmosphere, the nature of which is not known, though the causes giving rise to them may be obvious. Dr Majer records a case of a school at Ulm, of sixty or seventy boys, where the greater number were suddenly affected, on a warm day in May, with similar symptoms—giddiness, headache, nausea, shivering, trembling of the limbs, sometimes fainting. The attack occurred again the next day, and a common cause was certain. The room was enclosed by walls, in a narrow space, where the snow had lain all the winter: the wall was covered with fungous vegetation, and with salts from the mortar. From the sudden entrance of warm weather, fermentation had set in, and a strong marshy smell was produced; the substances of whatever kind generated in this way accumulated in the narrow, ill-ventilated space. Removal to a healthier locality at once cured the disease.

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[1] At Southampton the smell is perceptible at a distance of two miles.

[2] Vernois, *Hygiène Indus.*, t. ii. p. 60.

[3] Pappenheim's *Beit. der Sanitat. Pol.*, Heft ii.

CHAPTER V.

VENTILATION.[1]

THE term ventilation is not always used in the same sense. By some it is applied to the dilution and removal of all impurities which can collect in the air of inhabited rooms. The most common causes of such impurities are the respiration and cutaneous transpiration of men, the products of combustion of lights, the effluvia of simple uncleanliness of rooms or persons, the products of the solid or liquid excreta retained in the room, or, in hospital, discharges from the body or from dressings. In addition there may be special conditions which allow impure air to flow into a room, as from the basement of a house, from imperfectly trapped soil and waste pipes, or from other impurities outside a house.

It will be desirable, however, to restrict the term ventilation to the removal or dilution, by a supply of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of combustion of lights in ordinary dwellings, to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid and liquid excreta, and attention to the conditions surrounding dwellings.

The subject of ventilation may be conveniently considered under the following heads :—

1. The quantity of fresh air required for the purposes defined above.
2. The mode in which this quantity may be supplied.
3. The method of examining whether ventilation is sufficient or not; in other words, ascertaining that the air of inhabited rooms is pure according to a certain standard. This will form the subject of a separate section.

SECTION I.

QUANTITY OF AIR REQUIRED.

1. *Quantity required to dilute or remove the respiratory impurities caused by healthy persons.*

The impurities added to the air by respiration have been already enumerated.

The CO_2 which a human being adds to the air he dwells in is not in itself an important impurity, the amount being too small to exercise much influence on health; but it is practically in a constant ratio with the more important organic matter of respiration;—and, as it is readily determined with sufficient accuracy for practical purposes, it is taken as a convenient index to the amount of the impurities.[2]

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[1] For Army Regulation on Ventilation, see Book II. Chap. II.

[2] One of the earliest observers to recognise the value of carbonic acid as an index of purity appears to have been F. le Blanc, whose memoir, *Récherches sur la Composition de l'Air Confiné* (1842), is cited by General Morin. He appears to have had clearer notions as to the amount of air necessary than most of his contemporaries.

Pettenkofer, whose experiments are still the most trustworthy, ascertained that a man of twenty-eight years of age, weighing 132 ℔ avoir., evolved per hour at night during repose 0·56 of a cubic foot of CO_2, and 0·78 in the day time, using very moderate exertion :—during hard work the same man evolved 1·52 per hour. These amounts give the following :—

In repose, . .	0·00424	cub. ft. of CO_2 per ℔ of body-weight.
In gentle exertion,	0·00591	,, ,, ,,
In hard work, .	0·01227	,, ,, ,,

These figures are nearly in the ratio of 2, 3, and 6, and this may serve as a guide to the proportions of fresh air required. If we now take the average weight of adult males at 150 ℔ to 160 ℔, adult females at 100 ℔ to 120 ℔, and children at 60 ℔ to 80 ℔, we should have the following amounts of CO_2 evolved per hour in repose :—

Adult males, . .	0·636 to 0·678	cubic foot.
,, females, . .	0·424 to 0·509	,,
Children, . . .	0·254 to 0·339	,,

The estimate for children is probably too little, as tissue change is more active in their case.

For a mixed community a general average of 0·6 of a cubic foot per hour may be adopted; but for adult males, such as soldiers, it is advisable to adopt 0·7 to 0·72.

Taking the CO_2 as the measure of the impurity of the air vitiated by respiration and transpiration, in short, from the person in any way, we have to ask, What is to be considered the standard of purity of air in dwelling-rooms? We cannot demand that the air of an inhabited room shall be absolutely as pure as the outside air; for nothing short of breathing in the open air can insure perfect purity at every respiration.[1] In every dwelling-room there will be some impurity of air.

The practical limit of purity will depend on the cost which men are willing to pay for it. If cost is disregarded, an immense volume of air can be supplied by mechanical contrivances, but there are comparatively few cases in which this could be allowed.

Without, however, attempting too much, it may be fairly assumed that the quantity of air supplied to every inhabited room should be great enough to remove all sensible impurity, so that a person coming directly from the external air should perceive no trace of odour, or difference between the room and the outside air in point of freshness. This is now pretty generally admitted as the most convenient practical standard, precautions being taken that the air space be entered directly from the external air, or as nearly so as possible, for the sense of smell is rapidly dulled.

In a paper by Dr de Chaumont[2] it is shown, from a large number of observations (473 analyses), that the sense of smell carefully employed gives a very fair idea of the amount of impurity in an air-space. In these experiments the amount of CO_2 in the external air was determined at the same time, so that the respiratory impurity was accurately known. Dividing the observations into groups, the following results were obtained :—

[1] Thus the carbonic acid in the air being taken at ·04 per cent., and the carbonic acid of respiration being placed at ·6 cubic feet in an hour, a man placed in a room of 1000 cubic feet of air must receive no less than 1,000,000 cubic feet of outside air in an hour to reduce the carbonic acid to the standard (nearly ·0401 per cent.) of the fresh air.—"On Ventilation and Cubic Space," by Dr de Chaumont, Assistant Professor of Hygiene, Army Medical School, *Edinburgh Med. Jour.*, May 1867.

[2] "On the Theory of Ventilation," *Proceedings of the Royal Society*, No. 168, p. 187, 1875, and No. 171, 1876.

	1. Fresh, or not differing sensibly from the outer air.	2. Rather close. Organic matter becoming perceptible.	3. Close. Organic matter disagreeable.	4. Very close. Organic matter offensive and oppressive; limit of differentiation by the senses.
Mean CO_2 per 1000 vols. reduced to 0° Cent. (=32°F.), due to respiratory impurity,	0·1943	0·4132	0·6708	0·9054

It will thus be seen that the smell of organic matter is, on an average, perceptible to the sense of smell when the coincident CO_2, due to respiratory (or personal) impurity, reaches 0·1943 per 1000; and that when it exceeds 0·9054, smell is no longer able to detect shades of difference. We may therefore take 0·2 per 1000 in round numbers as the maximum amount of respiratory impurity admissible in a properly ventilated air space.

Adopting, then, this standard as the measure of the permissible maximum of impurity, the next point is the quantity of pure external air which should pass through the air of a room, vitiated by respiration, per head per hour, in order to keep the CO_2 at this ratio, assuming a general average of 0·6 of a cubic foot per head per hour to be given out. The following table gives the answer to this question, under different conditions of cubic space :—

TABLE *to show the degree of Contamination of the Air (in terms of CO_2) by Respiration, and the amount of air necessary to dilute to a given standard of* 0·2 *per* 1000 *volumes of air, exclusive of the amount originally present in the air.*

Amount of cubic space (=breathing space) for one person in cubic feet.	Ratio per 1000 of CO_2 from respiration at the end of one hour, if there has been no change of air.	Amount of air necessary to dilute to standard of 0·2 during the first hour.	Amount necessary to dilute to the given standard every hour after the first.
100	6·00	2900	3000
200	3·00	2800	3000
300	2·00	2700	3000
400	1·50	2600	3000
500	1·20	2500	3000
600	1·00	2400	3000
700	0·86	2300	3000
800	0·75	2200	3000
900	0·67	2100	3000
1000	0·60	2000	3000

For the sake of simplicity, the CO_2 naturally in the air has been disregarded, but, of course, there would be actually in the air from 0·3 to 0·4 volumes per 1000 more from this source. Thus (if we take it at 0·4), in the room of 100 cubic feet, there would at the end of an hour (·04 + ·6) = 0·64 volumes, or 6·4 per 1000, and in the room of 200 cubic feet there would be 0·34 volumes per cent., or 3·4 per 1000. The above table is calculated from this formula,[1]

$$\frac{(\rho_1 - \rho)c}{\rho} = d$$

where ρ_1 = Respiratory impurity per 1000 volumes existing in the air space c, stated in terms of CO_2.

ρ = Admissible limit of respiratory impurity, that is, 0·2 per 1000 volumes.

c = Air space, in cubic feet.

d = Amount of fresh air required, in cubic feet.

[1] See Dr F. de Chaumont's papers in the *Lancet*, Sept. 1866, and *Edin. Med. Journal*, May 1867; also Professor Donkin's Memorandum in the *Blue Book* of the Committee on the Cubic Space of the Metropolitan Workhouses (1867).

Thus the difference between the actual ratio of vitiation and the admissible limit, multiplied by the capacity of the air space and divided by the admissible limit, gives the amount of fresh air required.

Example: Let $\rho_1 = 1.$ and $c = 600$: then $\frac{1. - 0{\cdot}2}{0{\cdot}2} = 4$, and $4 \times 600 = 2400$ cubic feet of air required.

This formula is, however, inconvenient in form, and gives to *cubic space* an apparent importance which, as we shall see further on, it does not possess. The following is therefore better, as it is of general application.

$$\frac{e}{\rho} = d$$

where $e =$ the amount of CO_2 exhaled by one individual in an hour, $\rho =$ the limit of admissible impurity (stated per cubic foot), and $d =$ the required delivery of fresh air in cubic feet per hour. If ρ be expressed per 1000 volumes, then d must be taken to represent the *number of thousands* of cubic feet of air. If now we take e at the general average of 0·6 of a cubic foot, then:

$\frac{0{\cdot}6}{0{\cdot}0002} = 3000$ or $\frac{0{\cdot}6}{0{\cdot}2} = 3 =$ number of *thousands* of cubic feet of air required.

This formula may also be used conversely, in order to find from the condition of the air the average amount of fresh air which has been hitherto supplied and utilised. For this purpose we simply substitute for ρ (the admissible limit) ρ_1, the observed ratio. Thus, let us suppose that ρ_1, the observed ratio of vitiation, was 0·7 per 1000 vols., we should have:

$$\frac{0{\cdot}6}{0{\cdot}7} = 0{\cdot}857 = \textit{number of thousands} \text{ of cubic feet,}$$

or 857 cubic feet of air per head per hour had been supplied and utilised during the time of occupation.

We can also calculate the probable condition of an air space in which a given quantity of air is supplied: thus, $\frac{e}{d} = \rho_1$; taking the amount directed for soldiers in barracks, viz., 1200 per hour, we have (assuming that e represents in this case 0·72)

$$\frac{0{\cdot}72}{1200} = 0{\cdot}0006\ CO_2 \text{ per cubic foot, or } 0{\cdot}6 \text{ per 1000 vols.}$$

Where the quantity e is less than the above amounts, as for instance in the case of children, we should have, assuming children to evolve 0·4 of a cubic oot,

$$\frac{0{\cdot}4}{0{\cdot}2} = 2 = \textit{number of thousands} \text{ of cubic feet of air required.}$$

For a long time after this subject first attracted attention the amount of fresh air supposed to be necessary was put at too low a figure. Even the figures of General Morin,[1] which were a great advance at the time, are insufficient. He proposed 2118 cubic feet (60 cub. metres) for barracks at night, and Ranke adopts the same figures.

Roth and Lex[2] adopt the maximum of total impurity at 0·6 per 1000, which includes 0·4 of initial CO_2; and as they estimate the expired CO_2 as 20 litres,[3] or 0·706 cubic feet (Eng.), per hour, they give the hourly quantity of air as 100 cubic metres, or 3533 cubic feet.

1 *Rapport de la Commission sur le Chauffage et la Ventilation des Batimens du Palais de Justice*, Paris, 1860; also *Manuel Pratique du Chauffage et de la Ventilation*, 1874.
2 *Op. cit.*, p. 221.
3 This amount is also adopted by General Morin.

It is highly desirable that some general agreement should be come to as to the amount of air necessary, even if it be admitted that the desired amount cannot always be obtained. If we adopt the following amounts of CO_2 as being evolved during repose, we shall not be far from the probable truth :—

Adult males (say 160 lb weight), . .	0·72 of a cubic foot.
,, females (,, 120 lb ,,), . .	0·6 ,,
Children (,, 80 lb ,,), . .	0·4 ,,
Average of a mixed community, . .	0·6 ,,

Under those conditions the amount of fresh air to be supplied in health during repose ought to be—

For adult males, . .	3600	cubic feet per head per hour	= 102 c.m.
,, ,, females, . .	3000	,, ,, ,,	= 85 ,,
,, children, . .	2000	,, ,, ,,	= 57 ,,
,, a mixed community,	3000	,, ,, ,,	= 85 ,,

The amount for adult males as above given is just over 100 cubic metres, or, if we state it at 3600 cubic feet, it is just one cubic foot per second. These numbers are easy to remember.

When we have to deal with places, the inmates of which are actively employed, such as workshops and the like, the amount of air supplied must be proportionately increased. We have seen that in light work the CO_2 evolved per hour is nearly 0·006 of a cubic foot per lb of body-weight, and in hard work more than double that amount,—so that for a man of 160 lb weight we should have—

In light work, . . .	0·95 of a cubic foot of CO_2 evolved per hour.
In hard work, . . .	1·96 ,, ,, ,,

This would argue a delivery of fresh air as follows :—

In light work, . . .	4750 cubic feet.
In hard work, . . .	9800 ,,

Carnelley, Haldane, and Anderson[1] point out that the test by the sense of smell is liable to be influenced by many conditions, and that it not infrequently happens that a more overpowering odour is perceptible with a small than with a larger amount of CO_2. They propose the following standards :—0·6 CO_2 respiratory impurity for dwellings and 0·9 for schools; for organic matter 2·86 mgrms. of oxygen used per cubic metre (over outside air) : total micro-organisms 20 per litre over outside air, the ratio of *Bacteria* to *moulds* not to exceed 30 to 1. This is a liberal margin, which certainly ought not to be transgressed, arguing as it does not more than 1000 cubic feet of air per head per hour in dwellings and about 550 in schools.

It was stated long ago, from extensive observations, that in *mines*, if it was wished to keep up the greatest energies of the men, no less than 100 cubic feet per man per minute (= 6000 per hour) must be given; if the quantity were reduced to one-third, or one-half, there was a serious diminution in the amount of work done by the men. This amount included, of course, all the air wanted in the mine for horses, lights, &c.[2]

The amount for animals is an important question which has been little studied. Märcker[3] gives the following from experiments : —

For *large* cattle (viz., oxen, &c.) 30 to 40 cubic metres per hour for every 1000 lb weight, or 1 to $1\frac{1}{2}$ cubic foot for every lb weight.

For *small* cattle (viz., sheep, &c.) 40 to 50 cubic metres per hour for every

[1] *Phil. Trans.*, *loc. cit.*

[2] *Proceedings of the Inst. of Civil Engineers*, vol. xii. pp. 298 and 308.

[3] *Op. cit.*

1000 lb weight, or $1\frac{1}{2}$ to $1\frac{3}{4}$ cubic foot for every lb weight; the higher quantity being given on account of the more rapid tissue change in the smaller animals. These quantities seem absurdly small, and the chief reason for so limiting them seems to have been the fear of lowering the temperature too far. This is an erroneous view: animals properly fed will thrive better in a well-ventilated place at a low temperature than in a warmer place ill-ventilated. There seems no reason why the same rule should not apply to animals as to man, in which case something like 20 to 25 cubic feet per hour per lb of body-weight ought to be supplied. A horse or a cow ought, therefore, to have from 10,000 to 20,000 cubic feet per hour,—in short, it ought to be practically in the open air.

F. Smith,[1] using Dr de Chaumont's formula, $\frac{e}{p}=d$, where e (in a horse) equals 6·5, shows that the amount ought to be 32,500 cubic feet per hour, if the limit of respiratory impurity be assumed at 0·2 per 1000:—20,000 cubic feet would argue a limit of 0·325, and 10,000 feet would give 0·65. From the experiments given in Mr Smith's work (p. 44) the amount of air supplied ranged from 38,000 cubic feet per hour to 2900; in the latter case the smell is described as abominable. It is clear, therefore, that the amount of air ought to be as large as possible, and fortunately in the case of animals this can be accomplished without any great difficulty; as F. Smith considers that with proper feeding and attention the air about a horse may be changed every three minutes, or twenty times an hour, without danger, although the coat may not turn out so glossy as in a warmer stable.

2. *On the Quantity of Air required for Lights if the Air is to be kept pure by Dilution.*

Air must be also supplied for lights if the products of combustion are allowed to pass into the room. Wolpert has calculated that, for every cubic foot of gas, 1800 cubic feet of air must be introduced to dilute properly the products of combustion; and this is not too much if we remember that a cubic foot of good coal gas produces about 2 cubic feet of carbon dioxide, and that sulphur dioxide and other substances may be also formed. A common small gas-burner will burn nearly 3 feet per hour, and will consume 10 or probably 12 cubic feet in an evening (4 hours), and therefore from 18,000 to 21,600 cubic feet of air must be introduced for this purpose alone in the 4 hours, unless the products of combustion are removed by a special channel.[2] The power of illumination being equal, gas does not produce more CO_2 than candles (Odling), but usually so much more gas is burnt that the air is much more deteriorated; there is also greater heat and more watery vapour. The products should never be allowed to escape into the air of the room. Weaver has shown how important a source of impurity this is; and the bad effects of breathing the products of gas combustion are well known.

One lb of oil demands, for complete combustion, 138 cubic feet of air; and, to keep the air perfectly pure, nearly as much air must be introduced for 1 lb of oil as for 10 feet of gas. In mines, 60 cubic feet per hour are allowed for each light; the lights generally are dim, and the amount of combustion is slight; but this seems an extremely small amount.

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[1] *Veterinary Hygiene*, 1887.

[2] See an elaborate table by M. Layet, *Revue d'Hygiène*, vol. ii. pp. 1096, 97.

If gas is not burnt in a room, or in a very small amount, or if only candles or oil lamps are used, it is seldom necessary to take them into account in estimating the amount of air.

3. *On the Quantity required for the Respiration and Dilution of the Emanations of Sick Men.*

In making differential experiments among the healthy and the sick, it has been found[1] that among the former the smell of organic matter was still imperceptible when the air contained 0·208 per 1000 of respiratory impurity as CO_2; but in hospitals containing ordinary cases it was quite distinct when the CO_2 reached 0·166. From this we may conclude that the minimum amount of fresh air for hospitals ought to exceed that required in health by at least *one-fourth.* If 3000 cubic feet per hour be admitted as a general average in health, we may demand in round numbers 4000 in sickness; and if we have to deal with adult males only, such as soldiers, 4500 per head per hour. When we have to deal with serious cases, a still greater amount must be given, reaching 5000, 6000, or even more if possible,—in fact, the supply should be unlimited. These views are in accordance with the results of experimental inquiry (Grassi in Paris; Sankey in London; Sutherland).

In some diseases, so much organic substance is thrown off, that scarcely any ventilation is sufficient to remove the odour. In some of the London hospitals Dr de Chaumont found that there was still a close smell when 5000 cubic feet and even more were supplied, but the distribution was not perfect. Even when 3600 feet were supplied and utilised (as calculated from the CO_2), the ward was not free from smell. The best surgeons now consider an almost complete exposure of pyæmia patients to the open air the best treatment; and it is well known that in typhus fever and (to a less extent) in enteric, and also in smallpox and plague, this complete exposure of patients to air is the most important mode of treatment, before even diet and medicines. Even temperature must be sacrificed to a considerable extent, in order to obtain fresh air, if a choice requires to be made between the two.

Humidity.—The condition of the air as regards humidity is a matter of some importance, but has not hitherto been much considered. In Dr de Chaumont's experiments the mean humidity, in rooms having less than 0·2 per 1000 of respiratory impurity (reckoned as CO_2), was 73 per cent., at a temperature of 63° Fahr. This might be taken, provisionally, as a standard,[2] at least for climates like our own. In drier climates, however, as in America, such a condition would not be attainable in many cases, when the external air has a mean humidity of 40 or even 30 per cent. In Germany 50 per cent. is looked upon as an average humidity, whilst in England this would indicate an exceptionally dry atmosphere.

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[1] "The Theory of Ventilation," by Dr F. de Chaumont, *Proc. Roy. Soc.*, *loc. cit.*

[2] From the state of the air as regards humidity, information may sometimes be obtained which might take the place of the CO_2 determination, in the absence of means for carrying out the latter. For instance, at St Mary's Hospital, the air of the wards was found to have 78 per cent. of humidity, or 5·8 per cubic foot; to reduce it to 73 per cent., or 5·5 grains per cubic foot, while the external air contained 5·2, we should have $\frac{5 \cdot 8 - 5 \cdot 5}{5 \cdot 5 - 5 \cdot 2} = \frac{0 \cdot 3}{0 \cdot 3} = 1$, or we should require to add to the existing delivery of air at least as much more per hour as would equal the total cubic space. In the case referred to this was about 2256 cubic feet. The actual supply was 2080, total 4336 per head, or just about the quantity demanded for proper hospital ventilation.

SECTION II.

THE MODE IN WHICH THE NECESSARY QUANTITY OF FRESH AIR CAN BE SUPPLIED.

This is an engineering problem, and there can be no doubt that in time to come it will be as carefully considered by engineers as the supply of water, or the removal of the solid and liquid excreta. Ventilation is, in fact, the problem of the removal of the gasiform excreta of the lungs and skin.

SUB-SECTION I.—PRELIMINARY CONSIDERATIONS.

1. *Cubic Space.*[1]—A certain amount of fresh air has to pass through a given air space in a fixed time in order to maintain a certain degree of purity; the amount has been fixed at 3000 cubic feet for each healthy person in an hour; before considering the appliances for moving this air, we must consider what should be the minimum size of the air space through which the fresh air has to pass.

This will entirely depend on the rate at which air can be taken through the space without the movement being perceptible or injurious. The size of the space is of consequence, chiefly, in so far as it affects this condition. The larger the air space the less is the necessity for the frequent renewal of air, and the less the chances of draught. Thus a space of 100 cubic feet must have its air changed thirty times in an hour, if 3000 cubic feet of air are to be given, while a space of 1000 cubic feet need only have it changed three times in an hour for an equal ventilation.

When the most perfect mechanical means are employed, the air of even a small air space can be changed sufficiently often without draught. Thus, in Pettenkofer's experimental room at Munich, the air space is 424 cubic feet, and 2640 cubic feet can be drawn through by a steam engine in an hour without perceptible movement; in other words, the change is six times per hour nearly. With the best mechanical contrivances, and with disregard of cost, we are therefore certain that a cubic space of 600 feet would be sufficient, and there is every probability that engineers could ventilate even a smaller space without perceptible movement.

But if the mechanical contrivances are of an inferior kind, and particularly if natural ventilation is used, the difficulties of ventilating a small space are considerable, and are caused not so much by the rate of movement of the greater part of the air in the room, as by the rate at the openings where the fresh air comes in very quickly, and causes currents in the room. Suppose, for example, a space of 500 cubic feet occupied by one person, who has to be supplied with 3000 cubic feet in an hour; if the inlet opening be 12 square inches, the rate of movement through it would

[1] In the metropolitan lodging-houses, 30 superficial and 240 cubic feet are allowed; in the section-houses of the metropolitan police 50 superficial and 450 cubic feet are given. The Poor-law Board allows 300 cubic feet for every healthy person in dormitories, and from 850 cubic feet and upwards, according to circumstances, as far as 1200 cubic feet, for every sick person. In Dublin, an allowance of 300 cubic feet is required in the registered lodging-houses. —(From an excellent pamphlet, entitled *Essentials of a Healthy Dwelling*, p. 13.) In the Prussian army the allowance is 495 cubic feet (Prussian measurement, which is nearly the same as English), the superficial space being 42 to 45 square feet; in the old Hanoverian army the cubic space was 700 to 800 cubic feet (Prussian). The London School Board have given, in a general schoolroom, 10 square feet per scholar, and in graded schools 9 square feet; the height was ordered to be 13 feet—making 130 and 117 cubic feet respectively. This seems very small.

be 10 feet per second, or nearly 7 miles per hour; if 24 square inches, it would be 5 feet, or about 3·4 miles per hour.[1] In either case, in such a small room, the air could not be properly distributed before reaching the person, and a draught would be felt. If instead of 500 cubic feet of space 1000 be given, the problem is easier, for the small current of fresh air mixing with the larger volume of air in the room is more easily broken up, and the inmate being further from the opening, the movement is less felt. The question, in fact, turns in great measure on the power of introducing the air without draught.

If the renewal of air is carried on by what is termed natural ventilation, under the ordinary conditions of this climate, a change at the rate of six times per hour, as in Pettenkofer's room, could not be attempted. Even five times per hour would be too much; for, in barracks with 600 cubic feet per head, the rooms are cold and draughty when anything approaching to 3000 cubic feet per head per hour are passing through, that is, a change of five times per hour for each 600 cubic feet of air space. A change equal to three times per hour is generally all that can be borne under the conditions of warming in this country, or that is practically attainable with natural ventilation, and if this be correct, from 1000 to 1200 cubic feet should be the minimum allowance for the initial air space.

With good warming and an equable movement, which, however, are not always easy to get, there might be larger inlets, and therefore more easy distribution and a smaller air space to begin with. If the inlets are 48 square inches, the rate through them to supply a space of 500 cubic feet with 3000 cubic feet per hour would be only $2\frac{1}{2}$ feet per second; and if, as should be the case in artificial ventilation, the inlet is 72 or 80 square inches in size, the rate would only be a little over $1\frac{1}{2}$ foot per second, which would be imperceptible even at the orifice. But there is an argument against a small cubic space, even with good mechanical ventilation, viz., that if anything arrests the mechanism for a time, the ratio of impurity from respiration increases much faster in a small than in a large space.[2]

The warmth of the moving air influences the sensation of the persons exposed to it. At a temperature of 55° or 60°, a rate of $1\frac{1}{2}$ foot per second (= 1 mile per hour nearly) is not perceived; a rate of 2 to $2\frac{1}{2}$ per second (1·4 and 1·7 miles per hour) is imperceptible to some persons; 3 feet per second (2 miles per hour nearly) is perceptible to most; a rate of $3\frac{1}{2}$ feet is perceived by all persons; any greater speed than this will give the sensation of draught, especially if the entering air be of a different temperature,

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[1] For 1 square foot of opening at the rate of 1 foot per second, the supply would be 3,600 cubic feet per hour; if the rate be 10 feet per second, the supply would be 36,000 cubic feet, $\frac{1}{12}$ of this is 3000, and $\frac{1}{12}$ of 1 square foot (144 square inches) is 12; hence 12 square inches of opening, and 10 feet per second of velocity, give 3000 cubic feet per hour; of course the same result is obtained if we double the opening, making it 24 square inches, and halve the velocity, making it 5 feet per second.

[2] Experimental data on many of these points are still wanting. In prisons, with cells for separate confinement and artificial ventilation, the amount of space is seldom under 750 to 800 cubic feet, and practically this is found to be too small.

In Pentonville Prison, on Jebb's system, the air was hardly ever changed three times in the hour, during Dr de Chaumont's experiments, although the cells are nearly 800 cubic feet in capacity. The mean supply of air per hour was about 1056 cubic feet. In Gosport military prison, also on Jebb's principle (but not perfectly carried out), the mean supply was about 800 cubic feet, but the cells are only about 600 in capacity. In Aldershot military prison (not on Jebb's principle), with cells about 600 cubic feet in size, the mean supply was under 500. And in Chatham convict prison, where the cells are only 200, the mean supply was about 480. Wilson (*Handbook of Hygiene*) appears to have found the air changed in the large cells at Portsmouth convict prison about three times in the hour, and in the small about four times; this, however, is certainly not the rule.

or moist. If the air be about 70° Fahr., a rather greater velocity is not perceived, while if it be still higher (80° to 90° Fahr.), the movement becomes again more perceptible, and this is also the case if the temperature be below 40° Fahr. If the air could be warmed to a certain point in a cold climate, or if the climate be warm, there may be a much more rapid current, and consequently a smaller cubic space might be given. The subject of ventilation is in cold climates connected inseparably with that of warming, for it is impossible to have efficient ventilation in cold weather without warming the air.

The amount of cubic space thus assigned for healthy persons is far more than most people are able to have; in the crowded rooms of the artizan class, the average entire space would probably be more often 200 to 250 cubic feet per head than 1000. The expense of the larger rooms would, it may be feared, be fatal to the chance of such an ideal standard being generally carried out; but, after all, the question is, not what is likely to be done, but what ought to be done; and it is an encouraging fact that in most things in this world, when a right course is recognised, it is somehow or other eventually followed.

So, in the case of soldiers, the amount of authorised regulation space (600 cubic feet) is below the standard now given, but still the space is as much as can be demanded at present, as it has been found very difficult, without incurring greater expense than the country would bear, to give every man even the 600 cubic feet.

For sick persons the cubic space should be more than for healthy persons. We are to remember that there are other impurities besides those arising from respiration and transpiration, and that immediate dilution and as speedy removal as can be managed are essential.

Very much the same considerations apply to sick as to healthy men, except that the allowance of air in all cases of acute diseases must be greater; and, therefore, especially if natural ventilation be employed, the cubic space has to be enlarged also, to insure good distribution without draught, for surface chilling must be carefully avoided.

Admitting that, in hospitals, a minimum of 4000 cubic feet of fresh air per patient per hour should be supplied, if the change of air is to be three times per hour, as the best available rate of movement, the cubic space must be about 1300 cubic feet. A consideration of another kind may aid in determining the question as regards sick men. In hospitals a certain amount of floor space is indispensably necessary; first, for the lateral separation of patients; secondly, for convenience of attendance. For the first object, the greater floor space the better; and in respect of the second, Sir H. Acland has clearly shown that the *minimum* floor space for convenient nursing should be 72 square feet per bed.[1] In a ward of 12 feet in height this would give only 864 cubic feet, which is much too small.

Considering, however, the immense benefit to patients of pure air, and the practical experience of hospital physicians, it is very desirable not to fix the floor and cubic space of hospital wards at the minimum of what may suffice. The desire of most hospital physicians and surgeons is to obtain for their patients, if they can, a floor space of 100 to 120 square feet, and a cubic space of 1500 to 2000 cubic feet, and in this they are right.

It must be distinctly understood that a minimum of floor space must be insisted upon in all cases, not less than $\frac{1}{12}$ of the cubic space.[2]

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[1] See *Report* of the Committee appointed to inquire into the cubic space of Metropolitan Workhouses, 1867, p. 12.

[2] On this subject see further in chapter on HABITATIONS.

A notion prevails among many people, that cubic space may take the place of change of air,—so that if a larger cubic space be given, a certain amount of change of air may be dispensed with, or less fresh air be required. This is quite erroneous; even the largest space can only provide sufficient air for a limited time, after which the same amount of fresh air must be supplied hourly, whether the space be large or small. This is shown by the table on page 177, and may also be mathematically demonstrated by the formula given below.[1] Even in a space of 10,000 cubic feet per head the limit of admissible impurity would be reached in a little over 3 hours, after which the same hourly supply of 3000 feet would be as necessary as in a space of 100 cubic feet.[2]

Cubic Space required for Animals.

The amount of space for animals has not been very carefully examined. If we followed the rule for men and gave one-third of the quantity of air supplied per hour, this would give for horses and cattle from 3000 to 7000 cubic feet. This, however, is probably not necessary, because change of air can be carried on more freely than in human habitations, and animals cannot close ventilators as men will often do. A floor space of 100 to 120 square feet would probably be sufficient, giving a space of 1200 to 1800 cubic feet, according to the height of the building. If this could be secured there is every probability that the results would be excellent. We might put the estimate roughly at 2 cubic feet of space for every ℔ avoir. the animal weighs,—the floor space being not less than $\frac{1}{12}$ of the cubic capacity.

It was originally proposed that, in new stables, each horse should have 1605 cubic feet, and 100 square feet of floor space.[3] At present[4] the superficial area of army stables has been fixed as follows:—for the stall alone, 52 feet; for the stall and share of passage, 91 feet. F. Smith considers that the stall alone should be 70 feet, and the stall and share of passage, 100. In the Army Horse Infirmaries the superficial area is to be 137 square feet, or 200 with share of passage; loose boxes 204, and the cubic space 1900 feet per horse.

In the stables of cattle there is often excessive overcrowding, and it is well known that there is a vast amount of disease among them, which, however, is seldom allowed to go far, as they are sent to the butcher. Dr Ballard, who paid great attention to the cattle plague in Islington, recommended that at least 1000 cubic feet should be allowed per animal.

2. *Source of the Air supplied.*—In order that the object of the ventilation shall not be defeated, it is necessary that the air entering a room shall be

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[1] $\rho_1 = \frac{c}{d}\left(1 - \epsilon^{-\frac{dh}{c}}\right)$ where ρ_1=ratio of respiratory impurity at the time (h), (c) the amount of impurity involved during (h), (d) the supply of fresh air, (ϵ) exponential function, viz., 2·718, and (c) the capacity of the air space. Soon after the first hour the coefficient $\epsilon^{-\frac{dh}{c}}$ practically vanishes, and with it vanishes also the small influence the cubic space exercises.

[2] For further remarks on this point, see *Lectures on State Medicine*; also "Hygiene," in *Sanitary Record*, 1874-75, by Dr de Chaumont. In a pamphlet by General Morin, *Note sur l'Espace Cubique, &c.*, a table is given that might be misleading without explanation. It really shows the amount of air necessary to dilute a certain amount of impurity evolved in a certain cubic space, and is similar to the table given on page 177 of this work. For continuous ventilation, the necessary supply in any ordinary space for the first hour is a constant quantity. This can be shown by asymptote lines also. See paper by C. Herscher, "Société de Médecine Publique," in *Revue d'Hygiène*, vol. iii. p. 207.

[3] *Report of the Barrack and Hospital Improvement Commission on the Ventilation of Cavalry Stables*, 1866, p. 10.

[4] F. Smith, *Veterinary Hygiene.*

pure. The air must be the pure external air, and not be derived from places where it has stagnated and taken up impurities; if it is drawn along passages or tubes, and through louvres or basements, these should be capable of inspection and cleansing. All delivering air-shafts should, if possible, be short and easily cleaned. This is an important rule, and should lead to the rejection of all plans in which the air-shafts are long and inaccessible. Several instances have occurred of air being distributed by costly appliances, but drawn from an impure source, or allowed to be contaminated on its passage. Instead of perforated bricks, there should be sliding panels, or hinged flaps, so that the tube may be easily reached. In towns it may be necessary to filter the air, which is often loaded with the products of combustion and other impurities.

3. *Warming or Cooling of the Air.*—The air may require to be warmed to 60° or 65° Fahr., or cooled according to the season or locality. The warming in cold and temperate climates is a matter of necessity, as, if discomfort is caused by cold draughts, ventilation openings are certain to be closed.

4. *Distribution.*—The distribution in the rooms should be perfect, that is, there should be uniform diffusion of the fresh air through the rooms. The best way of ascertaining this is to compare the amount of air utilised, as calculated from the observed CO_2, with the actual movement of air, as measured with the air-meter. If the distribution is good, the two quantities ought not to differ materially. Much difficulty is found in properly managing uniform diffusion, and it requires careful arrangement of the various openings. The distributing plans should, if possible, prevent the chance of breathed air being rebreathed, especially in hospitals. As the ascent of respired air is rapid, on account not only of its temperature, but from the force with which it is propelled upwards, the point of discharge for patients in bed should be above.

By some it has been argued that it is better that the foul air should pass off below the level of the person, so that the products of respiration may be immediately drawn down below the mouth, and be replaced by descending pure air. But the resistance to be overcome in drawing down the hot air of respiration is so great that there is a considerable waste of power, and the obstacle to the discharge is sometimes sufficient, if the extracting force be at all lessened, to reverse the movement, and the fresh air forces its way in through the pipes intended for discharge. This plan, in fact, must be considered a mistake. The true principle is that stated long ago by D'Arcet. In the case of vapours or gases the proper place of discharge is above; but heavy powders, arising in certain arts or trades, which from their weight rapidly fall, are best drawn out from below.

Sub-Section II.—Means by which Air is set in Motion.

These are:—1*st*, the forces continually acting in nature, which produce what has been termed natural ventilation. 2*nd*, The forces set in action by man, which produce the so-called artificial ventilation.

The division is convenient, but not strictly logical, as the forces which act in natural do so also in artificial ventilation to a certain extent.

Natural Ventilation—General Statements.

Three forces act in natural ventilation, viz., diffusion, winds, and the difference in weight of masses of air of unequal temperature.

1. DIFFUSION.

As every gas diffuses at a certain rate, viz., inversely as the square root of its density, there is a constant escape of any foreign gas into the atmosphere at large. From every room that is not air-tight Pettenkofer and Roscoe have shown that diffusion occurs through brick and stone, and Pettenkofer believes that one of the evils of a newly built and damp house is that diffusion cannot occur through its walls. But ordinary plastered and papered walls reduce diffusion to a most insignificant amount. Through chinks and openings produced by imperfect carpentry the air diffuses fast, and Roscoe found that when he evolved carbonic acid in a room the amount had decreased one-half from that cause in 90 minutes.

The amount of purification produced by diffusion under ordinary circumstances is shown by observation to be insufficient; and, in addition, organic substances, which are not gaseous, but molecular, are not affected by it. As a general ventilating power, it is therefore inadequate.

2. THE ACTION OF THE WINDS.

The wind acts as a powerful ventilating agent, and in various ways. If it can pass freely through a room, with open doors and windows, the effect it produces is immense. For example, air moving only at the rate of 2 miles an hour (which is almost imperceptible), and allowed to pass freely through a room 20 feet broad, will change the air of the room 528 times in one hour. No such powerful action as this can be obtained in any other way.

The wind will pass through walls of wood (single-cased), and even of porous bricks or stone; and perhaps this will account for the fact that such houses, though cold, are healthy habitations. By covering a brick with wax, or inclosing a portion of a brick wall in an air-tight box, Pettenkofer has shown that the force of the breath will drive air through the brick, and will blow out a candle on the other side if the current of air be collected in a small channel. The force required to drive the air through is, however, really considerable, as the air in the brick must be brought into a state of tension.

Märeker[1] has given the following as the amount of air passing in one hour through a square metre of wall space, when the difference of temperature is 1° C.:—Sandstone, 1·69; limestone, 2·32; brick, 2·83; tufaceous limestone, 3·64; and loamy brick, 5·12 cubic metres of air. The little porosity of sandstone depends on the amount of moisture it holds. The moisture, in fact, greatly influences the transit. Plaster, however, appears to arrest wind, if it be true, as stated, that in the interior of some thick walls, after many years, lime has been found still caustic; and Märcker also notices the obstructive effects of mortar.

There are two objections to winds as ventilating agents by perflation.

(1) The air may be stagnant. In this country, and, indeed, in most countries, even comparative quiescence of the air for more than a few hours is scarcely known. Air is called "still" when it is really moving at 1 or 1½ mile an hour. The average annual movement of the air in this country is from 6 to 12 miles per hour; but it varies, of course, greatly from day to day, and in different places. The mean movement at Netley (average of

[1] *Untersuch. über nat. und künstliche Ventilation*, Göttingen, 1871.

13 years) is about $10\frac{1}{3}$ miles per hour; at Aldershot it is $12\frac{1}{2}$ miles per hour (mean of 5 years).

(2) A much more serious evil is the uncertainty of the movement and the difficulty of regulation. When the velocity reaches 5 or 6 feet per second, unless the air be warm, no one will bear it. The wind is therefore excluded, or, if allowed to enter directly through small openings, is badly distributed. Passing in with a great velocity, it forces its way like a foreign body through the air in the room, causing draughts, and escaping, it may be, by some opening without proper mixing. A current entering in this way may be measured for many feet.

But the wind acts in another way. A moving body of air sets in motion all air in its vicinity. It drives air before it, and, at the same time, causes a partial vacuum on either side of its own path, towards which all the air in the vicinity flows at angles more or less approaching right angles. In this way a small current moving at a high velocity will set in motion a large body of air.

The wind, therefore, blowing over the tops of chimneys, causes a current at right angles to itself up the chimney, and the unequal draught in furnaces is owing, in part, to the variation in the velocity of the wind. Advantage, therefore, can be taken of this aspirating power of the wind to cause a movement of air up a tube. The wind, however, may impede ventilation by obstructing the exit of air from any particular opening, or by blowing down a chimney or tube. This is, in fact, one reason of the failure of so many systems of ventilation; they may work well in a still atmosphere, but the immense resistance of the wind has not been taken into account. At 3 miles an hour, the pressure of the wind is $\frac{3}{4}$ of an ounce on each square foot; it is 1 ounce at $3\frac{1}{2}$ miles; 2 ounces at 5 miles; 4 ounces at 7 miles; $\frac{1}{2}$ ℔ at 10 miles; and 1 ℔ at 14 miles. At Netley the average pressure is a little over $\frac{1}{2}$ ℔ per square foot.

In some systems of ventilation the perflating power of the wind has been used as the chief motive agent. In Egypt the wind is allowed to blow in at the top of the house through large funnels. This plan has been in use from time immemorial. This was the case in Mr Sylvester's plan, which was used at Derby and Leicester fifty or sixty years ago. A large cowl, turning towards the wind, was placed in a convenient spot near the building to be ventilated—a little above the ground if in the country, or at some height if in a town. The wind blowing down the cowl, passed through an under-ground channel to the basement of the house, and entered a chamber in which was a so-called cockle stove or calorifere of metal plates or water or steam pipes, by which the air was warmed. It then ascended through tubes into the rooms above, and passed out by a tube or tubes in the roof, which were covered by cowls turning from the wind. So that the aspiratory power of the air was also used. This plan is extremely economical, but the movement of the air is unequal, and it is difficult to regulate it. It has been proposed to place a fan in the tunnel to move the air in periods of calm, and the plan then becomes identical in principle, and almost in detail, with the method of Van Hecke.

Mr Ritchie[1] has employed a similar plan in the ventilation of a dwelling-house. The air is warmed in winter to about 70° Fahr.; every room has a longitudinal opening over each door, concealed by the architrave, and regulated by valves, and through this the warm air from the staircase enters the rooms, and then passes up the chimney, and up outlet air-flues

[1] *Treatise on Ventilation*, by Robert Ritchie, C.E., 1862, p. 89.

placed in the walls, commencing at the ceiling, and ending at the wall-heads under the roof.

Dr Arnott ventilated the Field Lane Ragged School on this principle with excellent effect. In that case, as in all others, the movement was also in part carried on by the third cause of motion in air, viz., the effect of unequal density of masses of air.

In the ventilation of ships the wind is constantly used; and by wind-sails, and tubes with cowls turning towards the wind, air is driven between the decks and into the hold.

In using the wind in this way, the difficulty is to distribute the air so that it shall not cause draughts. This is best done by bending the tubes at right angles two or three times, so as to lessen the velocity, by enlarging the channel towards the opening in the interior of the vessel, and by placing valves to partially close the tubes, if necessary, and by screens of wire gauze.[1]

In all cases in which the air of a room, as in a basement story, or in the hold of a ship, perhaps, is likely to be *colder* than the external air, and when artificial means of ventilation cannot be employed, the wind should be taken advantage of as motive agent.

Fig. 27. Diagram of Fixed Upcast Cowl.

The aspiratory power of the wind can be secured by covering air-shafts with cowls such as that shown in fig. 27, which aid up currents and prevent down draughts. This is practically the plan on which all the varieties of up-cast ventilators are constructed, however varied may be their external appearance.

3. MOVEMENTS PRODUCED BY UNEQUAL WEIGHTS OF AIR.

The wind itself is caused by this power; but it is necessary, in discussing ventilation, to look upon this as if it were an independent force. If the air in a room be heated by fire, or the presence of men or animals, or be made moister, it endeavours to expand; and if there be any means for it to escape, a portion of it will do so, and that which remains will be lighter than an equal bulk of the colder air outside. The outer air will then rush into the room by every orifice, until the equality of weight outside and inside is re-established. But as the fresh air which comes in is in its turn heated, the movement is kept up in a constant stream, cold air entering by one set of orifices, and hot air escaping by another.

We have now to inquire how the rate of this constant stream of air may be calculated.[2] The mode most generally used is based on two well-known laws:—first, that the velocity in feet per second of falling bodies is equal to (nearly) 8 times the square root of the height through which they have fallen; and, second, that fluids pass through an orifice in a partition with a velocity equal to that which a body would attain in falling through a height equal to the difference in depth of the fluid on the two sides of the

[1] As the use of perforated zinc plates and of wire-gauze is very common in ventilation, it is necessary to bear in mind that these screens very soon get clogged with dirt. In all cases they should be so arranged as to be easily inspected and cleaned; and it should be a matter of routine duty to see that they are constantly kept clean. It should also be understood that the delay by friction through the fine wire-gauze is exceedingly great.

[2] Many of these points are given in Hood's *Treatise on Warming and Ventilation*, and in Wolpert (*Principien der Vent. und Luftheizung*), and are also discussed in Péclet (*Traité de la Chaleur*, 3rd edit.) and by General Morin (*Etudes sur la Ventilation*, Paris, 1863, t. ii.), to which reference is made for those who wish to enter into the mathematical part of the inquiry.

partition.[1] The pressure of air upon any surface may be represented by the weight of a column of air of uniform density of a certain height. Thus the pressure of the atmosphere at the surface of the earth is nearly 15 lb on the square inch, and this would be the weight of a column of air of about 5 miles in height. Air, therefore, rushes into a vacuum with a velocity equal to that which a heavy body would acquire in falling from a height of 5 miles, viz., 1304 feet per second. But if, instead of rushing into a vacuum, it rush into a chamber in which the air has less pressure than outside, its velocity will be that due to a height which represents the difference of pressure outside and inside. In ordinary cases this difference of pressure cannot be obtained by direct observation, but must be inferred from the difference of temperature of the outer and inner air. Air is dilated one part in 491 of its volume for every degree of Fahrenheit (or 1 in 273 for every degree of centigrade) that its temperature is raised, consequently the difference of pressure outside and inside will be as follows :—

The height from the aperture at which air enters to that from which it escapes, multiplied by the difference of temperature between outside and inside, and divided by 491.

If the height be 20 feet, and the difference of temperature 15 degrees, we have the height to produce velocity of inflowing current $= \frac{20 \times 15}{491} = 0{\cdot}61$ of a foot, and the velocity $= 8\sqrt{{\cdot}61} = 8 \times {\cdot}781 = 6{\cdot}248$. This, however, is the theoretical velocity. In practice an allowance must be made for friction of $\frac{1}{4}$th, $\frac{1}{3}$d, or even $\frac{1}{2}$, according to circumstances. The deduction of $\frac{1}{4}$th would leave 4·686 linear feet per second as the actual velocity. If this be multiplied by the area of the opening, in feet, or decimals of a foot,[2] the amount of air is expressed in cubic feet per second, and multiplying by 60 will give the amount per minute.

A table is given on page 211 in which this calculation has been made for all probable temperatures and heights; but it must be remembered that the movement is greatly influenced by the wind.

This cause of movement is, of course, constantly acting when the temperature of the air changes. It will alone suffice to ventilate all rooms in which the air is hotter than the external air, but will not answer when the air to be changed is equal in temperature to, or colder than, the external air.

As its action is equable, imperceptible, and continuous, it is the most useful agency in natural ventilation in cold climates, in inhabited and warm rooms; and in all habitations arrangements should be made to allow it to act. As the action increases with the difference of temperature, it is most powerful in winter, when rooms are artificially warmed, and is least so, or is quite arrested in summer, or in hot climates, when the internal and external temperatures are identical.

4. LOSSES PRODUCED BY FRICTION FROM VARIOUS CAUSES.

This aspect of the question has hardly received the attention it deserves, and its neglect is apt to lead to failure and disappointment. The chief causes of loss are the following :—

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[1] This is frequently called the rule of Montgolfier. The formula is $v = \sqrt{2gH}$; g being the acceleration of velocity in each second of time, viz., 32·18 feet, and H the height of the descent.

[2] It will be found always easier to take the area in decimals of a foot instead of inches; but if it be taken in inches, multiply the linear discharge in feet by the number of square inches, and divide by 144.

1. *Length of Tube or Shaft.*—Here with equal sectional areas the loss is directly as the length, so that if we take a shaft of 30 feet as a standard, a shaft of 40 feet long would have an increased friction of one-third.

2. *Size of Opening.*—For similar sections the friction is inversely as the diameter. Thus for two openings, respectively 1 and 2 feet in diameter, the friction at the smaller opening will be twice that of the larger. In this way dividing up an opening into a number of smaller openings, the aggregate of which is equal to the original opening, produces a loss by friction in the direct ratio of the diameters. An opening of 1 square foot divided into 4 openings of $\frac{1}{4}$ of a square foot loses in the ratio of $1 : \frac{1}{2}$, being respectively the diameters of the openings. When the shapes of the openings are not similar, the ratio may be stated as that of the square roots of the areas. Thus 1 square foot divided into nine openings, each equal to $\frac{1}{9}$ of a square foot, will lose in the ratio of $1 : \frac{1}{3}$, the square roots of the respective areas.[1]

3. *Shape of Opening.*—A circular opening may be taken as the standard, that being the figure which includes the greatest area within the smallest periphery. The loss sustained from any other shape being used will be proportionate to its difference from a circle enclosing a similar area. Thus, if we have two openings, each of 1 square foot area, the one being a circle and the other a square, the length of periphery of the latter will be 4 feet, of the former $3\frac{1}{2}$; therefore the velocity of the current through the square opening will be $\frac{3\frac{1}{2}}{4}$ or $\frac{7}{8}$ of that through the circular opening.[2]

4. *Angles in the Tube or Shaft.*—This is a most serious cause of loss. The exact formula has not been distinctly determined, but it may be accepted, as in accordance with experiment, that every right angle diminishes the current by one half, so that two right angles in a tube would reduce it to $\frac{1}{4}$, and so on.[3] Yet it is no uncommon thing to find tubes and shafts bent recklessly at numerous angles to fit a cornice or architrave, to save expense and appearance.

5. The presence of dust, soot, or dirt of any kind seriously interferes with the current, but this may of course be obviated with a moderate amount of care and attention.

It is obvious that attention to the above points is necessary to obtain success in any scheme of ventilation. To take an example :—let us suppose a straight shaft 30 feet long, sectional area circular, of 1 square foot,—the current through this giving a sufficient amount of air for the purpose required. Let it be necessary to produce a similar amount of ventilation in another place, but to use smaller shafts, square in section, area of each $\frac{1}{4}$ of a square foot,—each shaft being 40 feet long, and having one right angle in its course ; what would be the relative amounts of air available, other things being equal ? Taking the circular shaft, we have length of shaft 30, length of periphery $3\frac{1}{2}$, multiplying together we have $105 =$ friction. In the four smaller shafts we have length 40, length of periphery of each 2, which multiplied by $4 = 8$, then $40 \times 8 = 320$, the right angle doubles

[1] See General Morin's observations.

[2] For a table of friction due to form of sectional area, see "Hygiene," in *Sanitary Record*, 1875, by Dr F. de Chaumont.

[3] The formula $\frac{1}{1+\sin^2\theta}$ expresses the condition approximately between 0° and 90°; but $\frac{1+\cos\theta}{2}$ is of more general application, including any angle between 0° and 180°. In either case 90° shows a loss of *one-half*.

the friction, so that $320 \times 2 = 640$ compared with 105. Thus the result would be more than 6 to 1 in favour of the single shaft. It would be obviously necessary to increase the number of the smaller shafts or the size of each of them at least six times.

It is advisable generally to widen slightly the openings of shafts, especially if they are of small diameter, as the current tends to be contracted and obstructed at that point. At every change of direction the same thing takes place. Hence the desirability of rounding off angles as much as possible, where they cannot be altogether avoided.[1]

It is generally best to have the sections of shafts circular or elliptical instead of rectangular, for not only is there less loss by friction originally, but there is also less chance of lodgment of dust, &c., and they can be more easily and thoroughly cleaned.

5. PRACTICAL APPLICATION OF THE GENERAL STATEMENTS OF NATURAL VENTILATION.[2]

1. No particular arrangements are necessary to allow diffusion to act, except that there shall be communication between two atmospheres.

2. To obtain the perflation of the wind, windows should be placed, in all cases where it can be managed, at opposite sides of a room. The windows should open at the top, and in case the wind has a high velocity, means should be taken to distribute it. This can be done by sloping the window inwards when it opens, or a board may be placed obliquely upwards from the top sash of the window, when it opens in the usual way; then the air striking against the board is thrown up towards the ceiling. Or, wire-gauze may cover the space left when the window is open. The velocity of the wind is checked by the gauze, and the current is minutely divided. The gauze, however, must be kept clean.

Various plans have been proposed by different persons. The panes of glass may be made double, spaces being left at the *bottom* of the outside pane and at the *top* of the inner one, so that the wind is obliged to pass up between the two panes before it enters the room. Or, the lower sash being raised, and a piece of wood placed below it, the air is allowed to pass through the space left between the upper and lower sashes (Hinckes Bird.) Or, glass louvres, which can be more or less closed, are placed in one of the panes of the window; or a number of holes are obliquely bored through the panes, through which the air may pass up towards the ceiling before it intermixes with the air of the room. In Lockhead's ventilator there is a frame over the glass louvre, with a regulator in the centre. In Cooper's ventilator a movable plate of glass can be brought by a handle over the opening.

Stallard proposed to ventilate workshops and factories by having a double ceiling; the lower ceiling to be made of zinc or oiled paper, perforated with very numerous small holes; and the space between the two ceilings to be freely open to the air on all sides; thus there would be almost open-air breathing, as the communication with the external air would be constant and at all parts of the room.

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[1] On this question see Wolpert, *Theorie u. Praxis der Ventilation u. Heizung* (1879), p. 210 *et seq.*

[2] A very good account of the various plans in natural ventilation will be found in Mr Edward's work, *On the Ventilation of Dwelling-Houses*, 1868, in which figures of the plans are given; see also Eassie, "Dictionary of Sanitary Appliances," *Sanitary Record*, 1880-82; *Our Homes*, Cassell & Co., 1883; *Healthy Dwellings*, by D. Galton, 1880, Clarendon Press.

Besides windows, special openings may be provided for the wind to blow through, as in the plans already referred to of Mr Sylvester and Dr Arnott.

In all warm climates, where no chill can be produced by wind, it is a good plan to make the walls entirely pervious. Nothing can be better than the ventilation of the bamboo matted houses in Burmah. The wind blows through them, but it is so broken up into currents that it is not in the least unpleasant. Even in colder parts of India, the upper parts of the walls might be made thus pervious, provision being made to cover them, if necessary, in the cold season.

Cowls have been a good deal recommended as aids to ventilation, but the labours of the Committee of the Sanitary Institute of Great Britain, though not yet completed, have shown that the majority of them have no superiority over the open tube. The only form which seemed fairly good was the common *lobster-backed* cowl. For general use, however, this would require to revolve, and this is objectionable, as all revolving arrangements are liable to get out of order. A fixed cowl, consisting merely of a cone as a cap and a similar flange round the rim of the pipe, ensures a fairly constant up-draught (fig. 27). A reversed arrangement (fig. 28) ensures a constant down-draught. All apparatus of this kind (as already mentioned) are based upon these two principles, however varied their external appearance may be.

Fig. 28. Diagram of a Fixed *Down-cast* Tube, with trumpet mouth and inverted conical cap.

Another plan for utilising the action of the wind is by the use of "Ellison's conical bricks," which are pierced with conical holes, about $\frac{2}{10}$ of an inch diameter externally and $1\frac{1}{4}$ in. internally, depth $4\frac{1}{2}$ in. The wind blowing on them is so distributed as to be imperceptible as a draught in the room.

3. The movement produced by the difference of weight of unequally heated bodies of air will, of course, go on through all the contrivances just mentioned. But as in cold climates windows and doors must sometimes be shut, no room of any kind should be without additional openings, which may permit this movement from unequal temperature to go on. The great difficulty here is to exclude the action of the wind: and, in fact, it is impossible to do so; but, as far as possible, the openings should be protected from the perflating influence of the wind, so that only its aspirating force should be acting. They should be capable of being lessened in size, when the difference of the external and internal temperatures is great. As long as there are openings, movement will go on; and it does not really matter, as long as there is proper distribution, where the air comes in or goes out, or whether its direction is constant or not. In fact, it scarcely ever is constant, so liable is the direction to be altered by winds, by the action of the sun heating one side of a room, by the unequal distribution of heat in the room, &c. Still it seems desirable, as far as it can be done, to make such arrangements as shall give the movement of air a certain direction; and therefore in most systems, some of the openings are intended for the admission of fresh air, and are called *inlet*, *entrance*, or *adduction* openings; others are intended for the discharge of impure air, and are termed *outlet*, *exit*, or *abduction* openings.

Total size of all the special openings, whether intended for Inlets or Outlets.—As the movement of air increases with temperature, the size of the apertures can only be fixed for a certain given temperature; and as the efflux of hot air increases with the height of the column (supposing the temperature is equal throughout), a different size has also to be fixed for different heights.

This causes a difficulty in fixing the proper size for ventilating openings in the case of natural ventilation, as the conditions are so variable. The theoretical size for any required change of air, supposing the conditions were constant, may be obtained from the table at p. 211, which is calculated from Montgolfier's formula, with a deduction of $\frac{1}{4}$th for friction.

Thus, say that the height of the heated column is 20 feet, and the difference of temperature between the air in the room and that outside is 20° F., the linear rate of discharge as stated by the table (allowance being made for friction) is 322 feet per minute, or 19,320 feet per hour. If the opening were 1 square foot this would give 19,320 cubic feet per hour. But if 3000 cubic feet per hour are wanted for one person, the orifice of 1 square foot, or 144 square inches, is too large, and must be lessened in the proportion of 3000 to 19,320 $\frac{3000 \times 144}{19{,}320} = 22$ square inches (round numbers), *i.e.*, reduced to 22 square inches. There must be a corresponding space for entry, making the total ventilating opening 44 square inches.

To take another example; let us say the heated column is 15 feet, the difference of temperature 10° F., and the required supply for one person 2000 cubic feet. The table gives the linear rate as 197 feet per minute, or 11,820 per hour; an orifice of 144 square inches would then give 11,820, and an orifice of 24 square inches would give 2000; $\left(\frac{2000 \times 144}{11{,}820} = 24\right)$. But if in the above conditions 3000 cubic feet hourly supply were wanted, the opening must be 36 square inches. These examples show how impossible it is to fix any size which shall meet all conditions, even if the influence of wind could be completely excluded, which is impossible. The only way is to adopt a size which will meet most cases and supply means of altering the size according to circumstances. In this country, a size of 24 square inches per head for inlet, and the same for outlet, seems calculated to meet common conditions; but arrangements should be made for enabling this to be lessened or closed in very cold weather, or if the influence of strong winds is too much felt.[1] Moreover, the size must be in part dependent on the size of the room, because in a small room with many people it is

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[1] The following formula, proposed by Dr de Chaumont, can be used instead of the table on p. 211. It is based on Montgolfier's formula, with the discharge calculated for the hour and for square inches, instead of for the minute and the linear discharge, as in the table.

Let h be the height of the heated column of air; t its temperature; t' the temperature of the external air; 0·002 the ratio of expansion of air for each degree of Fahr.; 100 a constant; and f the coefficient of friction. Let D be the delivery required per hour, and Φ the total inlet and outlet area in square inches. Then to find Φ:

$$\frac{D}{100f(\sqrt{h(t-t')\times 0{\cdot}002})} = \Phi.$$

Example: Suppose, as in the text, that the heated column be 20 feet, its mean temperature 65°, and that of the outer air 45°, and the required delivery be 3000 cubic feet per hour; let f also equal $\frac{3}{4}$ or 0·75.

$$\frac{3000}{100 \times 0{\cdot}75(\sqrt{20(65° - 45°) \times 0{\cdot}002})} = 44{\cdot}4$$

square inches for inlet or outlet, or 22·2 for inlet alone.

A converse formula by Dr de Chaumont may be also useful. If the area of the inlet opening (Φ') is known, to find the delivery per hour under conditions h, t, and t'.

$$200f(\sqrt{h(t-t' \times 0{\cdot}002})\Phi' = D.$$

The constant 200 is obtained by multiplying 3600 (seconds per hour) by twice the square root of 16·09 (=8 nearly), and dividing by 144 square inches. By halving this constant we get the number for both inlet and outlet together.

impossible to have the size so great as it would be if each person's area of ventilation opening were 48 square inches, unless some portion of the air were warmed.

Relative size of the Inlets and Outlets.—It is commonly stated that, as the heated air expands, the outlets should be larger than the inlets, and the great disproportions of 5 to 4 and 10 to 9 have been given. As, however, the average difference of temperature is only about 10° to 15° Fahr. in this country, the disproportion is much too great, as a cubic foot of air only expands to 1·020361 cubic feet with an increase of 10°. Even if the difference is 30° Fahr., a cubic foot of air only becomes 1·061 cubic feet, which is equal to an increase of about $\frac{1}{17}$th. The difference is so slight that it may be neglected, and the inlets and outlets can be made of the same size.

It is desirable to make each individual inlet opening not larger than 48 to 60 square inches in area, or enough for two or three persons; and to make the outlet not more than 1 square foot, or enough for six persons. Distribution is more certain with these small openings.

Position and Description of the Inlet and Outlet Tubes.—1. *Inlets.*—The air must be taken from a pure source, and there must be no chance of any effluvia passing in. As a rule, the inlet tubes should be short, and so made as to be easily cleaned, otherwise dirt lodges, and the air becomes impure. Inlets should not be large and single, but rather numerous and small (from 48 to 60 inches superficial), so that the air may be properly distributed. They should be conical or trumpet-shaped where they enter the room, as the entering air, after perhaps a slight contraction, spreads out fan-like, and a slight back current from the room down the sides of the funnel facilitates the mixing of the entering air with that of the room. To lessen the risk of immediate down-draught they should turn upwards, if they are placed above the heads of the persons. Externally the inlets should be partly protected from the wind; otherwise the wind blows through them too rapidly, and, if the current be strong, draughts are felt; an overhanging shelf or hood outside will answer pretty well. Valves must be provided to partially close the openings if the wind blows in too strongly, or if the change of air is too rapid in cold weather. If covered with wire-gauze, it must be frequently cleaned.

Sometimes an inlet tube must be carried some distance to an inner room, or to the opposite side of a large room which is unprovided with cross-ventilation. In this case the heat of the room so warms the tube that the wind may be permitted to blow through it.

The position of the inlets is a matter of some difficulty. If there are several, they should be, of course, equally distributed through the room, so as to insure proper mixing of the air. They should not, however, be placed too near an outlet, or the fresh air may at once escape; theoretically, their proper place of entrance is at the bottom of the room, but if so, the air must in this climate be warmed; no person can bear the cold air flowing to and chilling the feet. The air can be warmed easily in various ways, viz.:—

(*a*) The air may pass through boxes containing coils of hot-water pipes, or (in factories) of steam pipes. This is the best mode of warming. The coils may be close to the outside wall, or in the centre, or in hospitals in boxes under the beds communicating with the exterior air, and opening into the ward.

(*b*) The air may pass into air-chambers behind or round grates and stoves, and be there warmed, as in the present barrack and hospital grate, contrived by Sir Douglas Galton: or as in the Meissner or Böhm stoves of

Germany;[1] or as in the terra cotta stove, in the Herbert Hospital at Woolwich.

(*c*) The air may be warmed in a tube passing through a stove, as in George's calorigen, or by the method of Bond's euthermic stove.

If the air cannot be warmed, it must not be admitted at the bottom of the room; it must be let in above, about 9 or 10 feet from the floor, and be directed towards the ceiling, so that it may pass up and then fall and mix gradually with the air of the room. The Barrack Commissioners have adopted this plan with half the fresh air brought into a barrack-room. The other half is warmed. It answers fairly well.

In towns or manufacturing districts the air is so loaded with particles of coal, or, it may be, other powders, that it must be filtered. Nothing answers better for this than muslin or thin porous flannel, or paperhangers' canvas, spread over the opening, which then should be made larger. This covering can be moistened if the incoming air be too dry.

The tubes proposed by Mr Tobin of Leeds provide for the introduction of air from the outside at the floor level and then up a vertical tube, about 4 feet in height; this gives a vertical direction to the current, which is retained for several feet further before it begins to spread and descend. The action of such a tube is, of course, much affected by the direction of the wind, and in some instances it is reversed altogether. The method is, however, useful in some cases, particularly for introducing air into places which could only be reached with difficulty by other means. It has been tried on a large scale at St Mary's Hospital, Paddington, with fair success.[2] In some forms (as made by the Sanitary Engineering Company), there is an arrangement for washing the air and arresting impurities. An ingenious contrivance for warming the air for the upright tube by means of a gas jet has been suggested by Mr Lawson Tait; it also provides an outlet for foul air. A modification for bedrooms and other rooms in private houses is also recommended by Mr Tobin, viz., to cut out slits between the sashes of the windows, so that the air enters vertically, even when the window is shut. This is similar in principle to other modifications of window ventilation already referred to, but it is only adapted for comparatively small rooms, and is quite inapplicable to a hospital ward or the like.

2. *Outlets.*—The place for the outlets is a most important consideration, as it will determine in great measure the position of the inlets. If there are no means of heating the air passing through them, they should be at the top of the room; if there are means of heating them, they may be at any point. If not artificially warmed, the highest outlet tube is usually the point of greatest discharge, and sometimes the only one.

(*a*) *Outlet Tubes without Artificial Heat.*—They should be placed at the highest point of the room; should be inclosed as far as possible within walls, so as to prevent the air being cooled; should be straight and with perfectly smooth internal surfaces, so that friction may be reduced to a minimum. In shape they may be round or square, and they may be covered above with some apparatus which may aid the aspirating power of the wind, and prevent the passage of rain into the shaft.

The causes of down-draught and down-gusts in outlet tubes are these: the wind forces down the air, rain gets in, and, by evaporation, so cools the air that it becomes heavier than the air in the room; or the air becomes too much cooled by passage through an exposed tube, so that it cannot

[1] The Germans appear to be now making great use of these ventilating stoves in hospitals, and even in private houses. For a good account, see Roth and Lex, *l. c.*, p. 248 *et seq.*

[2] See Dr de Chaumont's *Report*, *op. cit.*

overcome the weight of the superincumbent atmosphere; or another outlet shaft, with greater discharge, reverses the current.

Arrangements should be made to distribute the down-draught, if it occurs; flanges placed at some little distance below, so as to throw the air upwards again before it mixes with the air of the room, or simple contrivances of a similar kind, may be used. Valves should be also fixed to lessen the area of the outlet when necessary. If there are several outlet tubes in a room, all should commence at the same distance from the floor, be of the same height (or the discharge will be unequal), and have the same exposure to sun and wind.

Simple ridge openings may be used in one-storied buildings with slanting roofs; they ventilate most thoroughly, but snow sometimes drifts in. Rain may be prevented entering by carrying down the sides of the overhanging ridge for some little distance. A flange placed some little distance below will throw any down-draught towards the walls.

(*b*) *Outlets with Artificial Warmth.*—The discharge of outlets is much more certain and constant if the air can be warmed. The chimney with open fire is an excellent outlet—so good that in dwelling-houses, if there are proper inlets, no other outlet need be made, except when gas is used. When rooms are large, and more crowded, other outlets are necessary; the heat of the fire may be further utilised by shafts round the chimney, opening at the top of the room, or, in other words, by surrounding the smoke-flue with foul-air shafts.

Gas, if used, should in all cases be made to warm an outlet tube, both to carry off the products of combustion, and to utilise its heat. The best arrangement appears to be to place over the gas-jet a pipe to carry off the products of combustion, and to case the pipe itself with a tube, the opening of which is at the ceiling; the tube carrying off the gas products is hot enough to cause a very considerable draught in its casing, and thus two outlet currents are in action, one over the gas, and one from the ceiling round the gas-tube. A modification of the lamp proposed in 1846 by Mr Rutter answers very well, and is in use, as arranged by Mr Ricketts. A good form is also made by Messrs Sugg.

In various other ways the heat of fire and lights may be taken advantage of.

There will seldom be any difficulty in arranging the inlets and outlets, and in obtaining a satisfactory result, if these principles are borne in mind, viz., to have the fresh air pure, to distribute it properly, and to adopt every means of securing the outlets from cold, or artificially warming them, and of distributing the air, which, in spite of all precautions, will occasionally pass down them.

In hot climates, when outlet shafts are run up above the general level of the building, it would be of advantage to make them of brick work, and to colour them black, so that they may absorb and retain heat.

6. PLANS OF TUBES AND SHAFTS WHICH HAVE BEEN PROPOSED.

In most of the plans which have been proposed, the inventors have not distinctly seen that the influence of the winds and of the movement of air produced by unequal temperatures must be carefully distinguished, and, as far as can be done, provided for.

1. *Openings at once to the Outer Air for Inlets, the Chimney being relied on for the Outlets, or Special Tubes fixed in.*—Perforated or air bricks are let into the walls. A usual size is 9 × 3 inches, and the united area of all the

several openings in one brick is about $11\frac{1}{2}$ square inches. Another common size is 10×6 inches, with an open area of about 24 square inches. The wind blows freely through them, and draughts are produced.

The Sheringham valve is a great improvement on this: the air passes through a perforated brick or iron plate, and is then directed upwards by a valve opening, which can be closed, if necessary, by a balanced weight (fig. 29). The size of the internal opening is, in the usual-sized valve, 9 inches by 3, and the area is 27 inches. These valves are usually placed towards the upper part of the room. The wind blows through them, and the movement is therefore variable. They are often outlets; it will, in fact, depend upon circumstances whether they are inlets or outlets. Very little draught is, however, caused by them, unless with a high wind; on the whole, they are the best inlets of this kind.

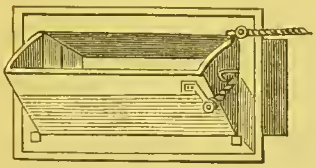

Fig. 29.

An open iron frame of the size of a brick, covered with perforated zinc, and with a valve to close it if necessary, is a still simpler plan, and the air is pretty well distributed. The gauze should be cleaned frequently. Mr Boyle used a round plate working on a screw, which can be brought nearer or farther from a corresponding opening in the wall; the air entering strikes on the plate, and then spreads circularly over the wall, and is then drawn gently into the room. Some ingenious forms of inlet and outlet have also been introduced by Mr Richard Weaver, C.E., and by Messrs Ellison of Leeds.

2. *Tubes of Different Kinds.*—A single tube has been sometimes used for inlet and outlet, a double current being established. This is, however, a rude plan, as there are no means of distributing the air, and as the intermingling of the current and the friction of the meeting air is sometimes so great as to impede, or even for a time stop, the movement.[1] To avoid these inconveniences, Watson proposed to place a partition in the tube (fig. 30), and Mure suggested the use of a double partition running from corner to corner, so as to make four tubes. He covered his divided tube with a louvre so as to make use in some degree of the aspiratory power of the wind on one side.

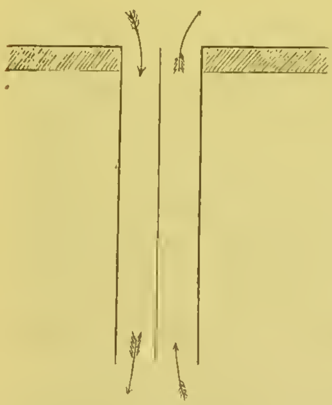

Fig. 30.

In these tubes, accidental circumstances, such as the sun's rays on one side, the wind, the fire in the room, &c., will determine which is outlet and which is inlet. They are so far better than the single tube, that the partition divides the currents and prevents friction, but there is the same irregular action and changing of currents from accidental circumstances, so that the direction of the currents and their rate are variable. The distribution of the entering air is also not good.

Much better than these plans is M'Kinnell's circular tube. It consists of two cylinders, one encircling the other, the area of the inner tube and

[1] The model of Watson's ventilating tube is well adapted for showing how opposing currents of air block each other. Although the tube is of good size, a candle placed in a bell glass, into the top of which the tube is fixed, soon goes out; a partition being then inserted into the tube, the currents are at once divided—one passes up, one down, the sides of the tube, and the candle burns again.

encircling ring being equal.[1] The inner one is the outlet tube; it is so because the casing of the other tube maintains the temperature of the air in it; and it is also always made rather higher than the other; above it is protected by a hood, but if it had a cowl, like that at fig. 27, it would be better. The outer cylinder or ring is the inlet tube; the air is taken at a lower level than the top of the outlet tube; when it enters the room it is thrown up towards the ceiling, and then to the walls by a flange placed on the bottom of the inner tube; the air then passes from the walls along the floor towards the centre of the room, and upwards to the outlet shaft. (Figs. 31 and 32.) Both tubes can be closed by valves. If there

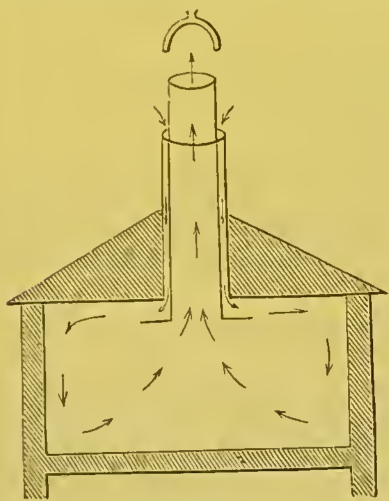

Fig. 31.

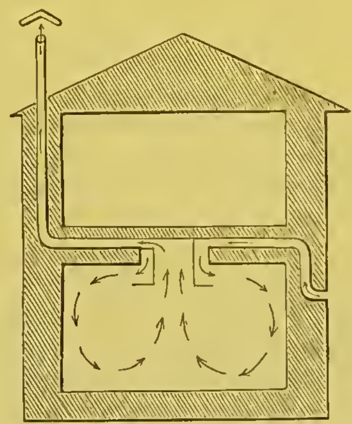

Fig. 32.

is a fire in the room, both tubes may become inlets; to prevent this the outlet tube should be closed; if doors and windows are open, both tubes become outlets.

The movement of air by this plan is imperceptible, or almost so; it is an admirable mode for square or round rooms, or small churches; for very long rooms it is less adapted.

Dr Arnott's chimney ventilator is a valved opening at the top of the room, leading at once into the chimney, and, like Dr Chowne's siphon, has the great advantage of drawing the air from the top of the room; it has been, and is, much used, but has the inconvenience of occasionally allowing the reflux of smoke; its action is also accompanied by a disagreeable noise.

Mr Boyle has altered this chimney ventilator by hanging small talc plates at a certain angle; a very slight pressure closes them and prevents reflux.

System of Ventilation adopted in the Army.

On Home Service.—The official plan now in use was arranged about twenty-six years ago by the Barrack Improvement Commission, and has answered well, so far it goes. It is based on the plan of natural ventilation, and consists of—

1. One *outlet* shaft, or more if required, proceeding from the highest point of the room; the exact position in the room varies; it is sometimes at the corner, or at one side, according to circumstances. This shaft is carried straight up inside the wall, and about 4 to 6 feet above the roof,

[1] It would be advisable to make the outer ring larger, seeing that the friction to be overcome is about double that of the inner tube.

and is covered with a louvre. It is made of wood, is very smooth inside, and is provided with a flap for partly closing it below. Its size is regulated by that of the room and by the number of inmates, but it is not made larger than 1 square foot; if more outlet is required, another shaft is put up. The relation between its size and that of the room varies with the position of the room. In a three-storied barrack the rule is as follows:—

(1) On the ground floor, 1 square inch of section area of outlet shaft for every 60 cubic feet of room space, or for each man 10 square inches of area.
(2) On the first floor, 1 square inch for every 55 cubic feet of room space, or for each man 10·9 (say 11) square inches.
(3) On the second floor, 1 square inch for every 50 cubic feet of room space, or for each man 12 square inches.

In a one-storied barrack the amount should be the same as the second floor, or, in other words, 12 men would have a shaft of 1 square foot. In addition, there is the chimney, which gives a section area per head of about 6 square inches. The total outlet area per man is therefore 16 to 18 inches, according to circumstances.

2. *Inlets.*—The amount of inlet is a trifle more than 1 square inch to every 60 cubic feet of room.

Half the inlet air is warmed in all the new barracks and many old barracks by being taken through air-chambers behind the fire (Galton's stove) (area of tube = 6 square inches per head), and the other half comes direct from the outer air into the rooms through an air brick delivering into the room through valves either louvred or hopper-shaped. In the latter form the air impinges on a baffle board, and is deflected right and left to openings protected by perforated zinc. This arrangement rather interferes with the free delivery of air. Area of outer opening = 5 square inches, making altogether 11 square inches of inlet opening per man.

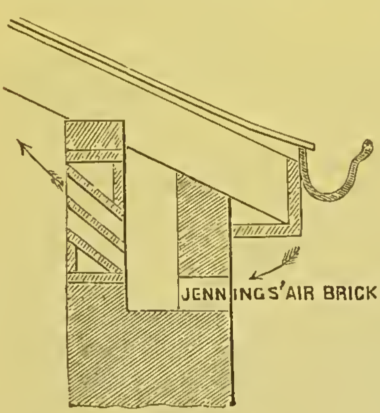

Fig. 33.

The cold-air inlets are placed at the sides near the ceiling, about 9 feet from the floor, and are not opposite each other. Fig. 33 shows a usual arrangement. The outlet space is thus seen to be rather larger than the inlet, but as the doors and windows seldom fit close, it is probable that practically this is of little consequence.

The movement of air through these openings is tolerably regular—as regular as it ever can be in natural ventilation. The discharge of air through the chimney and outlet shaft averages about 1200 cubic feet per head per hour, with a range from 700 to 1500 or 1600 according to the amount of fire, the warmth of the room, and the movement of the external air. The usual upward current through the outlet shafts at night is from 3 to 5 feet per second. Sometimes the chimney and outlet counteract each other a little; a strong chimney draught may stop the current in the outlet shaft, but there is seldom any down-draught unless rain beats into the louvre and trickles down the inside of the shaft. The ventilation of barracks has been wonderfully improved by this plan, and the average CO_2

ranges from 0·7 to 1 per 1000 volumes, equal to from 0·3 to 0·6 of respiratory impurity, according to the rapidity of movement of the air.

The hospital system is precisely the same, except that the dimensions are nearly doubled.

Mediterranean Stations.—The same system is directed to be carried out whenever practicable at Malta and Gibraltar, only the sizes of the inlets and outlets are trebled; for example, there is 1 square inch of outlet for every 20 cubic feet of space, instead of 60 as at home; great care is ordered to be taken to remove all outside obstacles to the movement of the wind.

The Tropics and India.—The same system in principle is now directed to be used in India.

SECTION III.

ARTIFICIAL VENTILATION.

Artificial ventilation is accomplished in two ways; either the air is drawn out of a building or room (the method by extraction), or it is driven in, so as to force out the air already in the room (the method by propulsion).

Sub-Section 1.—Ventilation by Extraction.

This is produced by the application of heat, so as to cause an upward current, or by the steam jet, or by a fan or screw, which draws out the air.

1. *Extraction by Heat.*—The common chimney is a well-known example of this. There is a constant current up the chimney, when the fire is burning, in proportion to the size of the fire and of the chimney. The usual current up a common sitting-room chimney, with a fair fire, is, as measured by an anemometer, from 3 to 6 feet per second. A very large fire will bring it up to 8 or 9 feet. The movement caused by a kitchen or furnace fire is, of course, greater than this. If the area of the section where the anemometer is placed be known, the discharge can be stated in cubic feet.

When the air enters equably, and is well distributed, the movement of air is from the inlets gently towards the fireplace; there is also said to be a movement, from above the fireplace, along the ceiling and down the walls, and then along the floor to the chimney.[1]

In the wards of Fort Pitt the current, with a good fire, is about $3\frac{1}{2}$ to $4\frac{1}{2}$ feet per second; and as the section area of the throat is 0·5 square foot, the average discharge is about 7200 cubic feet per hour. In the barracks at Chatham, Dr Fyffe found the discharge by the chimney to be 9080 cubic feet per hour (average of six observations). In the barracks at Gravesend, Messrs Hewlett, Stanley, and Reid found the discharge to be 6120 cubic feet per hour (average of twenty observations). At Chelsea New Barracks, with a fire alight but low, the velocity was 14·6 per second, or 21,038 cubic feet per hour; and, with the fire out, 11·9 per second, or 17,088 per hour.[2] In the experiments of the Barrack Commissioners,[3] the chimney discharge ranged from 5300 to 16,000 cubic feet per hour, the mean of twenty-five experiments being 9904 cubic feet. Even in summer, without a fire, there is generally a good up-current. In August 1869 Dr F. de Chaumont found at Fort Elson the velocity to be on one occasion 7·5 per second, and at

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[1] Reid and Stewart, quoted by the Barrack Commissioners.
[2] Dr F. de Chaumont's Reports, *Army Med. Reports*, vol. ix.
[3] *Report*, 1861, p. 73.

Gosport New Barracks, 8·4. The velocity generally ranges from 1½ feet to 3 feet per second, although it is often more. It may be concluded that, with an ordinary fire, a chimney gives a discharge sufficient for four or five persons. If then, more than this number of persons habitually live in the room, another outlet must be provided.

As the current up the chimney is so great when the fire is lighted, all other openings in a room, if not too many, become inlets; and, in this way, down-draughts of air may occur from tubes intended as outlets. There is no remedy for this; and if too much enters, the outlets must be more or less closed.

If the room be without openings, so that no air can reach the fire, air is drawn down the chimney, and a double current is established, by which the fire is fed. The down-current coming in puffs is one cause of smoky chimneys, aud may be at ouce cured by making an inlet.

The chimuey and fire form a type of a number of other similar modes of ventilatiou by extraction.

The ventilation of mines is carried on by lighting a fire at the bottom of a shaft (the upcast or return shaft), or half a shaft, if there be only one. The air is drawn down the other or downcast or intake shaft, or half the shaft, aud is then made to traverse the galleries of the mine, being directed this way or that by partitions. Double doors are used, so that there is no back or side rush of the air. The current passes through the up-cast shaft at the rate of from 8 to 10 feet per second; it flows through the main galleries at the rate of from 4 to 6 feet per second, or even more, and from 1000 to 2000 cubic feet per head per hour are supplied in good mines. In fire-damp mines much more than this is given, even as much as 6000 cubic feet per man per hour.[1] If the quantity of air be reduced too low, there is a serious diminution in the amount of work performed by the men. A horse is allowed 2466 cubic feet, and a light 59 cubic feet per hour. All these quantities are too small. It may easily be couceived how skilfully the air must be directed so as to traverse the most remote workings; in some mines a portion of air makes a circuit of from 30 to 40 miles before it can arrive at the upcast-shaft. The size of the shafts in a colliery varies from 8 to 11 or 12 feet in diameter, the sectional area of a shaft of the former size would be 50 square feet. A current of 8 feet per second in the upcast-shaft would give a discharge of 1,440,000 cubic feet per hour, which would give 720 men 2000 cubic feet per hour.

The sectional area and height of the extracting shaft, and of the tubes running into it, have been fixed by Péclet; the principle is to give to the shaft the greatest height which can be allowed, and the largest section which can be given,[2] without permitting the temperature of the contained air to fall so low as to be unable to overcome the resistance of the atmosphere at the top of the shaft, or the action of the winds.[3]

In large buildings the same plan is often used; a chimney (*cheminée d'appel* of the French) is heated by a fire at the bottom, and into the bottom of this shaft, close to the fire, run a number of tubes coming from the different rooms. Several French and English hospitals, and many other buildings, are ventilated in this way. Dr Reid for some years ventilated the Houses of Parliament in the same manner, and so powerful was his

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[1] *Proceedings of the Inst. of Civil Engineers*, vol. xii. p. 308.

[2] *De la Chaleur*, 3rd ed., 1861, t. iii. p. 66 *et seq.*

[3] The amount of the resistance given to the movement of air through the tubes leading to the shaft, and in the shaft itself, can be calculated from the formula given by Péclet, at p. 47 (t. iii.), but which it is unnecessary to introduce here.

up-draught that he could change the entire air in the building in a few minutes.

In dwelling-houses it has been proposed to have a central chimney, into which the chimneys of all the fires shall open, and to surround this with air-shafts connected with the tops of the rooms. It is supposed that if other inlets exist, there will be a current both up the chimney and up the shaft running beside it.

In all these cases it is necessary that the workmanship shall be very exact, so that air shall not reach the extracting shaft except through the tubes.

It is now more than a hundred and twenty years since Dr Mead brought before the Royal Society Mr Sutton's plan of ventilating ships on the same principle. Tubes running from the hold and various cabins joined together into one or two large tubes which opened into the ashpit beneath the cooking fires. If the doors of the ashpits were kept closed, the fires drew the air rapidly from all parts of the ship. Unfortunately, this plan never came into general use. The same plan was adopted by Dr Mapleton for the ventilation of the hospital ships employed in the last (1860) China War. The arrangement requires some watching to prevent careless cooks from allowing air to reach the fires in other ways.

On the same principle some men-of-war are now being ventilated.[1] The funnel and upper part of the boiler, and, as far as possible, all the steam apparatus, are inclosed in an iron casing, so that a space is left of some 3 or 4 feet between the casing and the funnel. When the fires are lighted, there is of course a strong current up this space; to supply this the air is drawn down through all the hatchways towards the furnace doors. The temperature of the stokehole is reduced from 130° or 140° Fahr. to 60° and 70°, and the draught to the fires is so much more perfect that more steam is obtained from the same amount of fuel. This plan, devised by Mr Baker, was ingeniously applied by Admiral Fanshawe, late superintendent at Chatham dockyard, to the ventilation of every part of the ship where there were no water-tight compartments. Edmunds' plan combines with this the ventilation, not only of the hold, but of the timbers of the ship.

Sometimes, instead of a fire at the bottom of the chimney, it is placed at the top; but this is a mistake, as there is a great loss of heat from the immediate escape of the heated air; the proper plan is to heat, as much as possible, the whole column of air in the chimney, which can only be done by placing the fire below. Sometimes, as in Jebb's method for cell prisons, the shaft is too short for the work it has to do.

Frequently, instead of or in addition to a fire, heat is obtained in the shaft by means of hot-water or steam pipes. This plan has long been in use in England,[2] and has since been introduced into France, and improved by M. Léon Duvoir. Warming, as well as ventilation, is accomplished by this method, which is in action at the Hospitals Lariboisière (in one-half) and Beaujon. After a very long investigation into the merits of all rival plans, it was adopted by a French commission for the warming and ventilation of the Palais de Justice at Paris, and has since been adopted in other public buildings, chiefly from the advocacy of General Morin.[3]

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[1] In the new ironclads it is found necessary to use large fans driven by special engines to effect thorough change of air below.

[2] It is in use in the Circuit Court-House in Glasgow, and in the Police Buildings at Edinburgh (Ritchie), and in many other buildings.

[3] Two excellent reports have been made by this Commission, of which General Morin was reporter. Their titles are given further on. Much information is also given in General Morin's work on ventilation, *Études sur la Ventilation*, Paris, 1863, 2 vols.; also *Manuel Pratique du Chauffage et de la Ventilation*, Paris, 1874.

Oil has been used in some cases instead of water, for circulating in the heating apparatus.

Very frequently, instead of a fire or hot-water vessels, lighted gas is used to cause a current, and if the gas can be applied to other uses, such as lighting, cooking, or boiling water, the plan is an economical one.

In theatres the chandeliers have long been made use of for this purpose. M. D'Arcet proposed this for several of the old theatres in Paris, and the Commission[1] appointed to determine the mode of ventilation to be adopted in the Théatres Lyrique et du Cirque Impérial, determined, after much consideration, that this plan was the best adapted for theatres. General Morin, from numerous experiments, found that 1 cubic metre of gas caused the discharge of 1000 cubic metres of air, or 1 cubic foot would cause the discharge of 1000 cubic feet of air.[2]

The advantage of extraction by heat, especially in the case of theatres and buildings where gas can be brought into play, are obvious, but the growing use of the electric light will necessarily modify the arrangements for ventilation.

There are some objections to extraction by the fire and hot-air shaft.

(1) The inequality of the draught. It is almost impossible to keep the fire at a constant height. The same quantity of combustible material should be consumed in the same time every day, and the heat should be kept in by large masses of masonry. Still, with these precautions, the atmospheric influences, and changes in the quality of the combustibles, cannot be avoided.

(2) The inequality of the movement from different rooms. From rooms nearest the shaft, and with the straightest connecting tubes, there may be a strong current, while from distant rooms the friction in the conduits is so great that little air may pass. This is well seen in cell prisons, ventilated on Jebb's principle. The greatest care is therefore necessary in calculating the resistance, and in apportioning the area of the tubes to the resistance. This plan is, indeed, best adapted for compact buildings. Occasionally, if the friction be great, from too small size or the angular arrangement of the conduits leading to the hot-shaft, there may be no movement at all in the conduits, but a down-current to feed the fire is established in the shaft itself—a state of things which was discovered by Dr Sanderson to exist formerly in the ventilation of St Mary's Hospital in London.

(3) The possibility of reflux of smoke, and perhaps of air, from the shaft to the rooms, is another objection of some weight.

(4) The impossibility of properly controlling the places where fresh air enters. It will flow in from all sides, and possibly from places where it is impure, as from closets, &c.; air is so mobile that with every care it is difficult to bring it under complete control—it will always press in and out at the point of least resistance.

2. *Extraction by the Steam-Jet.*—The moving agent here is the force of the steam-jet, which is allowed to pass into a chimney. The cone of steam sets in motion a body of air equal to 217 times its own bulk. Tubes passing from different rooms enter the chimney below the steam-jet, and the air is extracted from them by the strong upward current. This plan is best adapted for factories with spare steam. It was employed for some time in the ventilation of the House of Lords, but was finally abandoned.

3. *Extraction by a Fan or Screw.*—An extracting fan or Archimedean

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[1] *Rapport de la Commission sur le Chauffage et la Ventilation du Théatre Lyrique et du Théatre du Cirque Impérial*, Rapporteur le Général Morin, Paris, 1861.

[2] *Etudes sur la Vent.*, t. ii. p. 720.

screw has been used to throw out the air. Several different kinds have been proposed by Messrs Combes, Letoret, Glepin, and Lloyd, and have been used in coal-mines in Belgium, and in some of the English mines. At the Abercarn mine, in South Wales, a fan is used of 13½ feet diameter; the vanes, eight in number, are 3½ feet wide by 3 feet long; at 60 revolutions per minute the velocity of the air is 782 linear feet per minute, and 45,000 cubic feet are extracted; the velocity at the circumference of the fan is 2545 feet per minute; the theoretical consumption of coal per hour is 17·4 lb.[1]

Mr Van Hecke formerly used a fan for this purpose, in his system of ventilation of buildings, but he has found it better to abandon it, and substitute a propelling fan.

Sub-Section II.—Ventilation by Propulsion.

This plan was proposed by Desaguliers, in 1734,[2] when he invented a fan or wheel inclosed in a box. The air passed in at the centre of the fan, and was thrown by the revolving vanes into a conduit leading from the box. In some form or other this fan has been used ever since, and the conduits leading from it are now generally made large, so that the fan may move slowly, and deliver a large quantity of air at a low velocity. The fan, if small, is worked by hand; if large, by horse, water, or steam power. It is largely used in India, under the name of the Thermantidote.

The fans are often made with six or eight rays, each carrying vanes at the end, which should be as close as possible to the enveloping box. In size, the length of the vanes should be more than half the length of the rays; the number of rays should augment with the diameter of the orifice of access.[3]

The amount of air delivered can be told by timing the speed of revolution of the extremities of the fan per second, or per minute; the effective velocity is equal to ¾ths of this, and this is the rate of movement of the air. If the section area of the conduit be known the number of cubic feet discharged per second, minute, or hour, can be at once calculated.

The power of this plan is very considerable. With a fan of 10 feet diameter, revolving sixty times per minute, the effective velocity is 1414 feet per minute. The rate of movement in the main channel should not be more than 4 feet per second; the conduits must gradually enlarge in calibre; and the movement, when the air is delivered into the rooms, should not be more than 1½ feet per second. At the Hospital Lariboisière in Paris, it is stated that 150 cubic metres (= 5296 cubic feet) have been delivered per head per hour, in the wards ventilated by the propelling fan of MM. Thomas et Laurens. It must, however, be remembered, that the later observations of General Morin showed that much of the movement ascribed to the fan was really owing to natural ventilation.

This plan is very well adapted for those cases in which a large amount of air has to be suddenly supplied, as in crowded music halls and assembly rooms. St George's Hall at Liverpool is ventilated in this way. The air is taken from the basement; is washed by being drawn through a thin film

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[1] Ure's *Dictionary*, 1875, art. "Ventilation," vol. iii. p. 1069.

[2] *Course of Experimental Philosophy*, vol. ii. p. 564. The wheel was shown to the Royal Society in 1734.

[3] Péclet, *De la Chaleur*, 3rd edition, 1860, t. i. pp. 259, 263. Numerous kinds of fans for propulsion and extraction are figured, and detailed accounts of construction and amount of work are given.

of water thrown up by a fountain; is passed into calorifères (in the winter), where it can be moistened by a steam-jet, if the difference of the dry and wet bulb be more than four to six degrees, and is then propelled along the channels which distribute it to the hall. In summer, it is cooled in the conduits by the evaporation of water.

At the Hôpital Necker in Paris, and in many other places, the plan of Van Hecke is in use. A fan, worked by an engine, drives the air into small chambers in the basement, where it is warmed by cockle stoves, and then ascends into the rooms above and passes out by outlet shafts constructed in the walls. The system is effective and economical, though it is only just to say that, the use of the fan excepted, it is precisely similar in principle to Sylvester's.

The fans employed by Verity Brothers of London seem to be very powerful. Blackman's air-propeller is also a very powerful machine.

In addition to the fan, other appliances have been used. Soon after Desaguliers proposed the fan, Dr Hales employed large bellows for the same purpose, and they were used for some time on board some men-of-war, and in various buildings. They were worked by hand; and probably this, and their faulty construction, led to their being disused. Their use was revived and their form modified and improved by Dr Arnott.[1] Dr Arnott showed that Hales lost much power by forcing his air through small openings; and, by some ingenious alterations, made an effective machine. The hydraulic air-pump, sometimes used in mines, is useful on a small scale.[2] Norton's air-pump ventilator is another form.

The punkah used in India is another mechanical agent with a similar though more imperfect action. When a punkah is pulled in a room open on all sides, it will force out a portion of air, the place of which will be at once supplied by air rushing in with greater or less rapidity from all points. If the punkah can be moistened in any way, its cooling effect is considerable. In Moorsom's punkah a wheel turned by a bullock both moves the punkah and elevates water, which then passes along the top of the punkah, and flows down it.

The advantages of ventilation by propulsion are its certainty, and the ease with which the amount thrown in can be altered. The stream of air can be taken from any point, and can, if necessary, be washed by passing through a thin film of water, or through a thin screen of moistened cotton, and can be warmed or cooled at pleasure to any degree. In fact, the engineer can introduce into this operation the precision of modern science.

The disadvantages are the great cost, the chances of the engine breaking down, and some difficulties in distribution. If the air enter through small openings, at a high velocity, it will make its way to the outlets without mixing. The method requires, therefore, great attention in detail.

SECTION IV.

RELATIVE VALUE OF NATURAL AND ARTIFICIAL VENTILATION.

Circumstances differ so widely, that it is impossible to select one system in preference to all others. In temperate climates, in most cases, especially for dwelling-houses, barracks, and hospitals, natural ventilation, with such

[1] *On the Smokeless Fireplace*, by Neil Arnott, M.D., F.R.S., &c., 1855, p. 162; and in other publications.

[2] Ure's *Dictionary*, 1875, vol. iii. p. 1064.

powers of extraction as can be got by utilising the sources of warming and lighting is the best. Incessant movement of the air is a law of nature. We have only to allow the air in our cities and dwellings to take share in this constant change, and ventilation will go on uninterruptedly without our care.

In some circumstances, however, as in the tropics, with a stagnant and warm air; and in temperate climates in certain buildings, where there are a great number of small rooms, or where sudden assemblages of people take place, mechanical ventilation must be used. So much may be said both for the system of extraction and propulsion under certain circumstances, that it is impossible to give an abstract preference to one over the other. In fact, it is evident that the special conditions of the case must determine the choice, and we must look more to the amount of air, and the method of distribution, than to the actual source of the moving power. But in either case the greatest engineering skill is necessary in the arrangement of tubes, the supply of fresh air, &c. The danger of contamination of air as it passes through long tubes, and the immense friction it meets with, must not be overlooked. For hospitals, natural ventilation certainly seems the proper plan. The cost of the various plans will depend entirely on circumstances, the nature of the building, the price of materials, coal, &c. On the whole, the plans of ventilating and warming by hot-water pipes, and Van Hecke's plan, are cheaper than the method by propulsion by means of a large fan; but the latter gives us a method which is more under engineering control, and is better adapted for hot climates when it is desired to cool the air.

Comparing two sets of schools in Dundee, MM. Carnelley, Haldane, and Anderson[1] have shown that mechanical ventilation has the advantage. The incoming air is warmed by being driven by means of fans over hot pipes, and then delivered into the rooms, about 5 feet from the floor, through shallow broad openings; the outgoing air is drawn up from apertures about 2 feet from the floor into a chamber in the roof, and thence out through valved louvres. The mean delivery of air (calculated from the CO_2) in the mechanically ventilated rooms was 670 cubic feet per head per hour,—in those naturally ventilated, only 400; the range in the former being from 375 to 1680, and in the latter from 175 to 1370. In neither case, however, was the ventilation very good.

SECTION V.

EXAMINATION OF THE SUFFICIENCY OF VENTILATION.

The sufficiency of ventilation should be examined—

1st, By determining the amount of cubic space and floor space assigned to each person, and their relation to each other, and by determining the amount of movement of the air, or, in other words, the number of cubic feet of fresh air which each person receives per hour.

2nd, By examining the air by the senses, and by chemical, biological, and mechanical methods, so as to determine the presence, and, if possible, the amounts and characters of suspended matters, organic vapour, carbon dioxide, hydrogen sulphide, watery vapour, ammonia, &c.

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[1] *Phil. Trans.*, *loc. cit.*

Sub-Section I.—Measurement of Cubic Space.[1]

The three dimensions of length, breadth, and height are simply multiplied into each other. If a room is square or oblong, with a flat ceiling, there is, of course, no difficulty in doing this, but frequently rooms are of irregular form, with angles, projections, half-circles, or segments of circles. In such cases the rules for the measurement of the areas of circles, segments, triangles, &c., must be used. By means of these, and by dividing the room into several parts, as it were, so as to measure first one and then another, no difficulty will be felt. After the room has been measured, recesses containing air should be measured, and added to the amount of cubic space; and, on the other hand, solid projections, and solid masses of furniture, cupboards, &c., must be measured, and their cubic contents (which take the place of air) deducted from the cubic space already measured. The bedding also occupies a certain amount of space; a soldier's hospital mattress, pillow, three blankets, one coverlet, and two sheets, will occupy almost 10 cubic feet—about 7 if tightly rolled up. It is seldom necessary to make any deduction for tables, chairs, and iron bedsteads, or small boxes, or to reduce the temperature of the air to standard temperature, as is sometimes done.

A deduction may be made, however, for the bodies of persons living in the room; a man of average size takes the place of about $2\frac{1}{4}$ to 4 cubic feet of air (say 3 for the average.) The weight of a man in stones, divided by 4, gives the cubic feet he occupies. Thus a man weighing 12 stones occupies 3 cubic feet.

In linear measurement, it is always convenient to measure in feet and decimals of a foot and not in feet and inches.[2] If square inches are measured, they may be turned into square feet by multiplying by 0·007.

Rules—*Area or Superficies.*

Area of circle, . . . $= D^2 \times \cdot 7854$ (or πr^2, where r is the radius).

" " . . . $= C^2 \times \cdot 0796 \left(\text{or } \dfrac{C^2}{4\pi}\right)$.

Circumference of circle, . $= D \times 3\cdot 1416$ ($\pi 2r$).

Diameter of circle, . . $= C \div 3\cdot 1416 \left(= \dfrac{C}{\pi}\right)$.

Area of ellipse, . . = Multiply the product of the two diameters by ·7854 $\left(\dfrac{4ls}{\pi}\right)$.

Circumference of ellipse, . = Multiply half sum of the two diameters by 3·1416 $\left\{\pi \dfrac{l+s}{2}\right\}$.

Area of a square, . . = Square one of the sides, or multiply any two sides into each other.

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[1] For tables of useful measures, see Appendix.

[2] The following table may be found convenient:—

Inches.		Decimal parts of a foot.	Inches.		Decimal parts of a foot.
12	=	1·00	6	=	0·50
11	=	0·92	5	=	0·42
10	=	0·83	4	=	0·33
9	=	0·75	3	=	0·25
8	=	0·67	2	=	0·17
	=	0·58	1	=	0·08

Area of a rectangle, . . = Multiply two sides perpendicular to each other.

Area of a triangle, . . = Base $\times \frac{1}{2}$ height, or Height $\times \frac{1}{2}$ base.

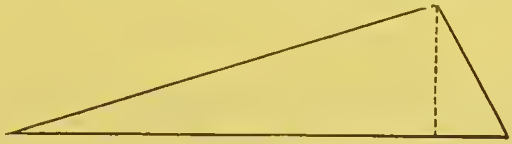

Fig. 34.

Area of a parallelogram, . = Divide into two triangles by a diagonal, and take sum of the areas of the two triangles.

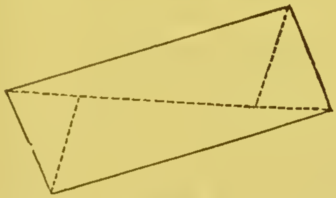

Fig. 35.

Any figure bounded by right lines, = Divide into triangles, and take the sum of their areas.

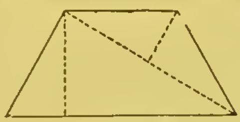

Fig. 36.

Area of segment of circle, . = To $\frac{2}{3}$ of product of chord and height add the cube of the height divided by twice the chord

$$(\text{Ch} \times \text{H} \times \tfrac{2}{3}) + \frac{\text{H}^3}{2\text{Ch}}.$$

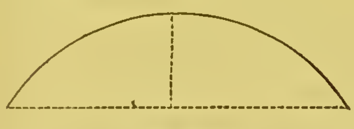

Fig. 37.

Cubic Capacity of a Cube or a Solid Rectangle.—Multiply together the three dimensions, length, breadth, and height.

Cubic Capacity of a Solid Triangle.—Area of section (triangle) multiplied by depth.

Cubic Capacity of a Cone or Pyramid.—Area of base $\times \frac{1}{3}$ height.

Cubic Capacity of a Dome.—Two-thirds of the product of the area of the base multiplied by the height (area of base $\times$ height $\times \frac{2}{3}$).

Cubic Capacity of a Cylinder.—Area of base $\times$ height.

Cubic Capacity of a Sphere.—$D^3 \times {\cdot}5236\left(\text{or } \frac{4\pi r^3}{3}\right)$.

The cubic capacity of a bell-tent may be taken as that of a cone resting on a short cylinder.

The cubic capacity of an hospital marquee must be got by dividing the marquee into several parts—1*st*, into body; and, 2*nd*, roof:—

1. Body, as a solid rectangle, with a half cylinder at each end.
2. Roof, solid triangle, and two half cones.

The total number of cubic feet, with additions and deductions all made, must then be divided by the number of persons living in the room; the result is the cubic space per head; whilst the total area of floor space divided by the number of persons gives the floor space per head, which should be as near as possible $\frac{1}{12}$ of the cubic space.

Sub-Section II.—Movement of Air in the Room.

The direction of movement must first be determined, and then its rate.

1. direction of movement.

First enumerate the various openings in the room—doors, windows, chimney, special openings, and tubes—and consider which is likely to be the direction of movement, and whether there is a possibility of thorough movement of the air. Then, if it is not necessary to consider further any movement through open doors or windows, close all these, and examine the movement through the other openings. This is best done by smoke disengaged from smouldering cotton-velvet, and less perfectly by small balloons, light pieces of paper, feathers, &c. The flame of a candle, which is often used, is only moved by strong currents. It may be generally taken for granted that one-half the openings in a room will admit fresh air, and half will be outlets. But this is not invariable, as a strong outlet, like a chimney, may draw air through an inlet of far greater area than itself, or may draw it through a much smaller area with an increased rapidity.

2. rate of movement.

The direction being known, it is only necessary to measure the discharge through the outlets, as a corresponding quantity of fresh air must enter.

By the Anemometer.—This is best done by an anemometer, or air-meter, of which there are several in the market. The one commonly used is in principle that invented by Combes in 1838: four little sails, driven by the moving air, turn an axis with an endless screw, which itself turns some small toothed wheels, which indicate the number of revolutions of the axis, and consequently the space traversed by the sails in a given time, say one minute. M. Neumann, of Paris, modified this anemometer by omitting most of the wheels, and introducing a delicate watchmaker's spring, which opposes the force of the wind, and, when it equals it, brings the sails to a stand-still. By a careful graduation (which must be done for each instrument), the rate per second is determined, and is indicated by a small dial and index.

Mr Casella, of Holborn, at the suggestion of the late Dr Parkes, modified and improved this instrument, and adapted it to English measures. A very beautiful instrument is thus available by which the movement of air can be measured approximatively very readily.[1]

Casella's air-meter is thus used:—Being set at the zero point, it is placed in the current of the air; if it is placed in a tube or shaft, it should be put well in, but not quite in the centre, as the central velocity is always greater than that of the side; a point about two-fifths from the sides of the tube will give the mean velocity. The time when the sails begin to move is accurately noted, and then, after a given time, the instrument is removed, and the movement, in the time noted, is given by the dial. A correction is then made, and the linear discharge is obtained.[2] If this linear discharge

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[1] Mr Saxon Snell has pointed out some sources of errors in the use of this instrument as regards the positive observations, but these are less important when the observations are comparative.

[2] All instruments require correction, as they never give the whole of the velocity. Great care must be taken to ascertain that the correction has been accurately determined, and they should be frequently compared with a standard instrument.

is multiplied by the section area of the tube or opening (expressed in feet or decimals of a foot), the cubic discharge is obtained. If the current varies in intensity, the movement should be taken several times, and the mean calculated; and if the tube is so small that the sails approach closely to the circumference, the results cannot be depended on. If placed at the mouth of a tube, it often indicates a much feebler current than really exists in the tube.

The cubic discharge per minute being known, the amount per hour is got by multiplying by 60, and this divided by the number of persons in the room, gives the discharge per head for that particular aperture.

An anemometer on a larger scale is fixed in some of the large outlets of

TABLE *to show the Velocity of Air in linear feet per minute. Calculated from Montgolfier's formula; the expansion of air being taken as* 0·002 *for each degree Fahrenheit, and one-fourth being deducted for friction.* (*Round numbers have been taken.*)

Height of column.	DIFFERENCE BETWEEN INTERNAL AND EXTERNAL TEMPERATURE.																						
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30
10	88	102	114	125	135	144	153	161	169	176	183	190	197	204	210	216	222	228	233	239	244	219	254	279
11	92	107	119	131	141	151	160	169	177	185	192	200	207	213	220	226	233	239	245	250	256	261	267	292
12	96	111	125	136	147	158	167	176	185	193	201	209	216	223	230	237	243	249	255	261	267	273	279	305
13	100	116	130	140	153	164	174	183	192	201	209	217	225	232	239	246	253	259	266	272	278	284	290	318
14	104	120	135	147	159	170	181	190	200	209	217	225	233	241	248	255	262	269	276	282	289	295	301	330
15	108	125	139	153	165	176	187	197	207	216	225	233	241	249	257	264	272	279	286	292	299	305	312	341
16	111	129	144	158	170	182	193	204	213	223	232	241	249	257	265	273	281	288	295	302	309	315	322	353
17	115	133	148	162	176	188	199	210	220	230	239	248	257	265	274	282	289	297	304	311	318	325	332	363
18	118	136	153	167	181	193	205	216	226	237	246	255	264	274	282	290	298	305	313	320	327	335	342	374
19	121	140	157	172	186	198	210	222	233	243	253	262	272	281	289	298	306	314	321	329	336	344	351	384
20	125	144	161	176	190	204	216	228	239	249	259	269	279	288	297	305	314	322	330	338	345	353	360	394
21	128	147	165	181	195	209	221	233	245	255	266	276	286	295	304	313	321	330	338	346	354	361	369	404
22	131	151	169	185	200	214	226	239	250	261	272	282	292	302	311	320	329	338	346	354	362	370	378	414
23	134	154	173	189	204	218	232	244	256	267	278	289	299	309	318	327	336	345	354	362	370	378	386	423
24	136	158	176	193	209	223	237	249	261	273	284	295	305	315	325	335	344	353	361	370	378	386	394	432
25	139	161	180	197	213	227	241	254	267	279	290	301	312	322	332	342	351	360	369	378	386	394	402	441
26	142	164	183	201	217	232	246	259	272	284	296	307	318	328	338	348	358	367	376	385	394	402	410	450
27	145	167	187	205	221	237	251	264	277	290	302	313	324	335	345	355	365	374	383	392	401	410	418	458
28	147	170	190	209	225	241	255	269	282	295	307	319	330	341	351	361	371	381	390	399	408	417	426	467
29	150	173	194	212	229	245	260	274	287	300	312	324	335	347	357	368	378	388	397	407	416	425	433	475
30	153	176	197	216	233	249	264	279	292	305	318	330	341	353	363	374	384	394	404	414	423	432	441	483
31	155	179	200	219	237	253	269	283	297	310	323	335	347	358	369	380	391	401	411	420	430	439	148	491
32	158	182	204	223	241	257	273	288	302	315	328	341	353	364	375	386	397	407	417	427	437	446	455	499
33	160	185	207	226	245	261	277	292	307	320	333	346	358	370	381	392	403	414	424	434	443	453	462	506
34	162	188	210	230	248	265	282	297	311	325	338	351	363	375	387	398	409	420	430	440	450	460	469	514
35	165	190	213	233	252	269	286	301	316	330	343	356	369	381	393	404	415	426	436	447	457	467	476	522
36	167	193	216	236	255	273	290	305	320	334	348	361	374	386	398	410	421	432	442	453	463	473	483	529
37	170	196	219	240	259	277	294	310	325	339	353	366	379	392	404	415	427	438	448	459	470	480	490	536
38	172	198	222	243	262	281	298	314	329	344	358	371	384	397	409	421	432	444	454	465	476	486	496	543
39	174	201	225	246	266	284	302	318	333	348	362	376	389	402	414	426	438	450	461	471	482	492	503	551
40	176	204	228	249	269	288	305	322	338	353	367	381	394	407	420	432	444	455	467	477	488	499	509	558
45	187	216	241	264	286	305	324	341	358	374	389	404	418	432	445	458	471	483	495	506	518	529	540	591
50	197	228	254	279	301	322	341	360	377	394	401	426	441	455	469	483	496	509	522	534	546	558	569	623
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30

To use the table, determine the height of the warm column of air from the point of entrance to the point of discharge. Ascertain the difference between its temperature and that of the external air. Take out number from Table, and multiply by the section-area of the discharge-tube or opening, in feet or decimals of a foot. The result is the discharge in cubic feet per minute, multiply by 60—result, discharge per hour. *Example.*—Height of column, 32 feet; difference of temperature between internal and external air, 17 deg. Looking in the table, we find opposite to 32 and under 17, 375 feet. That would be for an area of 1 square foot.

But supposing our air opening to be only ¾ of a foot, we must multiply 375 by ¾ or 0·75 of a foot.

$$\begin{array}{r} 375 \\ 0{\cdot}75 \\ \hline 1875 \\ 2625 \\ \hline 281{\cdot}25 \end{array}$$

Therefore we get 281 feet (per minute), multiplied by 60 = 16,860 feet per hour.

the Paris hospitals, showing the movement at every moment by means of an index and dial.[1]

By the Manometer.—Dr Sanderson has made an ingenious alteration of a manometer described by Péclet, which can also be employed to measure the pressure, and, by calculation, the velocity, of the air. The current of air is allowed to impinge on a surface of water, and the height to which the water is driven up a tube of known inclination and size gives at once a measure of force. But, as necessitating a little calculation, this instrument is less useful than the anemometer, though it is adapted for cases where the anemometer cannot be used, as it may be connected by a long tube with a distant room, and probably would be well fitted to measure constantly the velocity in an extraction shaft.

In measuring the movement of the air in chimneys, or places where either the heat or the dust would injure the air-meter, a manometer must be used. Mr Fletcher describes what appears to be a good one.[2]

By Calculation.—Supposing the external air is tranquil, and that the only cause of movement is the unequal weights of the external colder and the internal warmer air, the amount of discharge may be approximately obtained by the law of Montgolfier, already given. There is a fallacy, however, as the amount of friction can never be precisely known. Still, as an approximation, and in the absence of an anemometer, the rule is useful; and the accompanying table (p. 211) has therefore been calculated.

On testing this table, however, by the air-meter, it has been found to give too much when the tubes are long, on account of the great friction, and it is therefore advisable to make a further deduction of $\frac{1}{6}$th when the shaft or tube is long, and is at the same time of small diameter. If the tube has any angles, or is curved, this table is too imperfect to be used, unless attention be paid to the correction for friction already noted.

If the movement of the external air influences the movement in the room, as when the wind blows through openings, calculation is useless, and the anemometer only can be depended on.

For the chemical and biological examination of air, see BOOK III., EXAMINATION OF AIR

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[1] Péclet, *De la Chaleur*, t. i. p. 171, where the description will be found.
[2] *Fifth Annual Report of the Inspector under the Alkali Act*, Blue Book.

CHAPTER VI.

HABITATIONS.

Whoever considers carefully the record of the mediæval epidemics, and seeks to interpret them by our present knowledge of the causes of disease, will surely become convinced that one great reason why those epidemics were so frequent and so fatal was the compression of the population in faulty habitations. Ill-contrived and closely packed houses, with narrow streets, often made winding for the purposes of defence; a very poor supply of water, and therefore a universal uncleanliness; a want of all appliances for the removal of excreta; a population of rude, careless, and gross habits, living often on innutritious food, and frequently exposed to famine from their imperfect system of tillage,—such were the conditions which almost throughout the whole of Europe enabled diseases to attain a range, and to display a virulence, of which we have now scarcely a conception. The more these matters are examined, the more shall we be convinced that we must look, not to grand cosmical conditions; not to earthquakes, comets, or mysterious waves of an unseen and poisonous air; not to recondite epidemic constitutions, but to simple, familiar, and household conditions, to explain the spread and fatality of the mediæval plagues.

SECTION I.

GENERAL CONDITIONS OF HEALTH.

The diseases arising from faulty habitations are in great measure, perhaps entirely, the diseases of impure air. The site may be at fault; and from a moist and malarious soil excess of water and organic emanations may pass into the house. Or ventilation may be imperfect, and the exhalations of a crowded population may accumulate and putrefy; or the excretions may be allowed to remain in or near the house; or a general uncleanliness, from want of water, may cause a persistent contamination of the air. And, on the contrary, these five conditions insure healthy habitations:—

1. A site dry and not malarious, and an aspect which gives light and cheerfulness.
2. A pure supply and proper removal of water; by means of which perfect cleanliness of all parts of the house can be insured.
3. A system of immediate and perfect sewage removal, which shall render it impossible that the air shall be contaminated from excreta.
4. A system of ventilation which carries off all respiratory impurities.
5. A condition of house construction which shall insure perfect dryness of the foundation, walls, and roof.

In other words, perfect purity and cleanliness of the air are the objects to be attained. This is the fundamental and paramount condition of healthy habitations; and it must over-ride all other conditions. After it has been

attained, the architect must engraft on it the other conditions of comfort, convenience, and beauty.

The inquiries which have been made for many years in England have shown how badly the poorer classes are lodged, both in town and country, and how urgent is the necessity for improvement. Various Acts [1] have been passed for the purpose of improving labourers' cottages and other small dwellings, but either from the powers being insufficient, or from the difficulty of proving that a dwelling is injurious to health unless it is in extremely bad condition, these Acts have had only partial effect.

Up to a certain point, there is no difficulty in insuring that a small house shall be as healthy as a large one. The site and foundations can be made as dry, the drains as well arranged, the walls and roof as sound, and the water supply as good as in a house of much larger rental. In fact, in one respect, the houses of the poor are often superior to those of the rich, for the sewers do not open directly into the houses, and sewer air is not breathed during the night. But the difficulties in the houses of the poor are the overcrowding and the impregnation of the walls with foul effluvia and deposits. Considerations of cost will probably always prevent our poor class of houses from having sufficient floor and cubic space. These two special difficulties must be met by improved means of warming and ventilation, and by covering the interior walls with a cement which is non-absorbent, and which can be washed. Perhaps, also, improvements in using concrete, or other plans, will eventually so lessen the cost of building that larger rooms can be given for the same rental, and the poor be taught to prize the boon of an abundant allowance of air, and not to seek to lessen it by crowding and underletting.

Dryness of the foundation and walls of a house is secured by draining the subsoil, 4 to 9 feet below the foundation,[2] and, in very wet clay soil, by paving or cementing under the entire house.[3] The walls are kept dry by being imbedded in concrete, which is brought up to the ground level, or by the insertion in the walls themselves of a waterproof course of slate, asphalt, or, what is better, of ventilating vitrified thin bricks (as devised by Mr Taylor).

On wet, damp soils, when a house has no cellar, the flooring ought to be raised 2 feet above the ground, and the space below should be well ventilated. In the tropics, the houses are often raised on arches 3 to 5 feet above the ground. If this plan were universal, it would vastly improve the health of the community. Dryness of walls is best secured by hollow walls,[4] or coating the walls with cement, which is kept painted, or with slates. Terra-cotta slabs have been used, and liquid preparations (chiefly alkaline silicates) have been brushed over the surface of brick and stone. Bricks are often extremely porous,[5] and a brick wall will absorb many gallons of water.[6]

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1 *Labouring Classes Dwelling-House Act*, 1866; *An Act to provide Better Dwellings for Artisans and Labourers*, 1868; *Artisans' Dwellings Act*, 1875; various clauses in the different *Public Health Acts.*

2 Even the walls of old rickety cottages may be thoroughly dried by this means (Rogers Field).

3 For a good diagram of a plan for avoiding damp, see Bailey-Denton's *Sanitary Engineering*, plate i. p. 56.

4 Jenning's patent bonding brick is a good plan for preventing moisture penetrating from the outer to the inner skin of a hollow wall. It is a hollow, vitrified brick, curved upwards at an angle of 45°, so that no water can pass along it.

5 An ordinary brick will hold about 16 oz. of water, and one square foot of brickwork 9 inches thick will hold 6 gallons.

6 Bricks imperfectly burned on the outside of the kiln are termed Place, or Samel, or Sandel bricks. They absorb much water. The sun-dried bricks of India are very damp, and absorb water from the air. Many sandstones are very porous; water beats into them and rises high by capillary attraction. Lime made from chalk absorbs water. Pisé is compressed earth, and, unless covered with cement, is moist.

Dryness of the roof should be carefully looked to in every case, as water often gets to the walls through a bad roof, and the whole house becomes damp.

The condition of the basements or cellars, if they exist, requires attention, as the air of the house is often drawn directly from them. They should be dry, and thoroughly well ventilated, and the house pipes, if they run down to the basement, should always be uncovered so as to be easily inspected, and any bad-fitting joint or crack, or imperfect trap, if there be one inside the house, be at once remedied.

The carrying off of rain-water, so as not to sink into the ground near the house, is a matter of importance.

The other points which are necessary to secure a healthy house are discussed in their respective chapters.

In examining a house to discover the sources of unhealthiness, it is best to begin at the foundation, and to consider first the site and basements, then the living and sleeping rooms (as to size, cubic contents, and number of persons, and conditions of walls and floors), ventilation, water supply, and plans of waste and sewer-water removal, in regular order.

The following memorandum as to the way in which engineers examine a house has been kindly furnished by Mr William Eassie, C.E.:—

MEMORANDUM.

What is usually done by Sanitary Engineers when inspecting a House.

Sanitary engineers consider that an unusual smell is generally the first evidence of something wrong, and that, traced to its source, the evil is half cured. They inspect first the drainage arrangements. If the basement generally smells offensively, they search for a leaking drain-pipe, *i.e.*, a pipe badly jointed or broken by settlement, and these will often show themselves by a dampness of the paving around. If, upon inquiry, it turns out that rats are often seen, they come to the conclusion that the house drain is in direct communication with the sewer, or some old brick barrel-drain, and therefore examine the traps and lead bends which join the drain-pipes to see if they are gnawed or faulty. If the smell arises from any particular sink or trap, it is plain to them that there is no ventilation of the drain, and more especially no disconnection between the house and the sewer, or no flap-trap at the house-drain delivery into the sewer. If a country house be under examination, a smell at the sink will, in nearly every case, be traced to an unventilated cesspool; and, in opening up the drain under the sink, in such a state of things, they will take care that a candle is not brought near so as to cause an explosion. If the trap is full of foul black water, impregnated with sewer air, they partly account for the smell by the neglect of flushing. If the sink, and kitchen, and scullery wastes are in good order and the smell is still observable, they search the other cellar rooms, and frequently find an old floor-trap without water, broken and open to the drain. If the smell be ammoniacal in character, they trace the stable-drains and see if they lead into the same pit, and if so, argue a weak pipe on the route, especially if, as in some London mansions, the stable-drains run from the mews at the back, through the house to the front street sewer.

Should a bad persistent smell be complained of mostly in the bedroom floor, they seek for an untrapped or defective closet, a burst soil-pipe, a bad junction between the lead and the cast-iron portion of the soil-pipe behind the casings, &c., or an improper connection with the drain below. They will examine how the soil-pipe is jointed there, and, if the joint be inside the house, will carefully attend to it. They will also remove the closet framing, and ascertain if any filth has overflowed and saturated the flooring, or if the safe underneath the apparatus be full of any liquid. If the smell be only occasional, they conclude that it has arisen when the closet handle has been lifted in ordinary use or to empty slops, and satisfy themselves that the soil-pipe is unventilated. They, moreover, examine the bath and lavatory waste-pipes, if they are untrapped, and, if trapped by a sigmoidal bend, whether the trapping water is not always withdrawn owing to the syphon action in the full-running pipe. They will trace all these water-pipes down to the sewer, ascertain if they wrongly enter the soil-pipe, the closet-trap, or a rain-water pipe in connection with the sewer.

If the smell be perceived for the most part in the attics, and, as they consider, scarcely attributable to any of the foregoing evils, they will see whether or not the rain-water pipes which terminate in the gutters are solely acting as drain ventilators, and blowing

into the dormer windows. They will also examine the cisterns of rain-water, if there be any in the other portions of the attics, as very often they are full of putridity.

A slight escape of impure air from the drains may be difficult to detect, and the smell may be attributed to want of ventilation, or a complication of matters may arise from a slight escape of gas. Neither are all dangerous smells of a foul nature, as there is a close sweet smell which is even worse. Should the drains and doubtful places have been previously treated by the inmates to strongly smelling disinfectants, or the vermin killed by poison, the inspectors of nuisances will find it difficult to separate the smells. In such a case, however, they will examine the state of the ground under the basement flooring, and feel certain that there are no disused cesspools or any sewage saturation *of any sort.* They will also ascertain if there be any stoppage in the drain pipes, by taking up a yard trap in the line of the drain march, and noting the reappearance of the lime water which they had thrown down the sinks. And invariably, after effecting a cure for any evil which has been discovered, they will leave the traps cleaned out and the drains well flushed.

A thoroughly drained house has always a disconnection chamber placed between the house drain and the sewer or other outfall. This chamber is formed of a raking syphon, and about two feet of open channel pipe, built around by brickwork and covered by an iron man-hole. Fresh air is taken into this chamber by an open grating in the man-hole, or by an underground pipe, and the air thus constantly taken into the chamber courses along inside the drain, and is as continuously discharged at the ventilated continuations of the soil pipes, which are left untrapped at the foot, or at special ventilating pipes at each end of the drain. This air current in the drain prevents all stagnation and smell.

When a house is undergoing examination, it is wise to test for lighting-gas leakages, and there is only one scientific method of doing so, which is as follows:—Every burner is plugged up, save one, and to that is attached a tube in connection with an air force-pump and gauge—the meter having been previously disconnected. Air is then pumped into the whole system of pipes, and the stop-cock turned, and if, after working the pump for some time, and stopping it, the gauge shows no signs of sinking, the pipes may be taken as in safe condition; but if the mercury in the gauge falls, owing to the escape of air from the gas-tubes, there is a leak in them, which is discoverable by pouring a little ether into the pipe close by the gauge, and recommencing pumping. Very minute holes can be detected by lathering the pipes with soap and water, and making use of the pump to create soap bubbles.

Besides the drainage, they will, especially if they detect a bad and dank smell, see if it arises from the want of a damp-proof course or of a dry area, see if there be a wet soil under the basement floor, a faulty pipe inside the wall, an unsound leaden gutter on the top of the wall, or an overflowing box-gutter in the roof, a leaky slatage, a porous wall, a wall too thin, and so on.

They will also keep an eye upon the condition of the ventilating arrangements, and whether the evils complained of are not mainly due to defects there. The immediate surroundings of the house will also be noted, and any nuisances estimated.

Sanitary inspectors, whilst examining into the condition of the drains, always examine the water cisterns at the same time, and discover whether the cistern which yields the drinking water supplies as well the flushing water of the closets. They will also ascertain if the overflow pipe of the cistern, or of a separate drinking-water cistern, passes directly into the drain.

If the overflow pipe be syphon-trapped and the water rarely changed in the trap, or only when the ball-cock is out of order, they will point out the fallacy of such trapping, and, speaking of traps generally, they will look suspiciously on every one of them, endeavour to render them supererogatory by a thorough ventilation and disconnection of the drains.[1]

SECTION II.

HOSPITALS.

General Remarks.

Of late years a great number of works (English, French, German, and American) have been written on the construction of hospitals. This has

[1] Much useful information will also be obtained from *Sanitary Arrangements for Dwellings*, by W. Eassie, C.E., and from *Sanitary Engineering*, by J. Bailey-Denton, C.E. See also *The Habitation in Relation to Health*, by F. de Chaumont, Christian Knowledge series; *Our Homes, and how to keep them Healthy*, Cassell & Co.

been especially owing to the celebrated *Notes on Hospitals*, published by Miss Nightingale after the Crimean War—a work the importance of which it is impossible to over-rate—and to the very useful pamphlets of Mr Roberton, of Manchester. Among military writers, Robert Jackson in this as in all other points takes the first rank, and his observations on the construction of hospitals are conceived entirely in the spirit of the best writings of the present day. In the short space which can be given to the subject here, we can merely condense what has been best said on the subject, as applied especially to military hospitals.[1] In the first place, however, a few words are necessary on the general question.

Although the establishment of hospitals is a necessity, and marks the era of an advanced civilisation, it must always be remembered that if the crowding of healthy men has its danger, the bringing together of many sick persons within a confined area is far more perilous. The risks of contamination of the air, and of impregnation of the materials of the building with morbid substances, are so greatly increased, that the greatest care is necessary that hospitals shall not become pest-houses, and do more harm than good. We must always remember, indeed, that a number of sick persons are merely brought together in order that medical attendance and nursing may be more easily and perfectly performed. The risks of aggregation are encountered for this reason; otherwise it would be far better that sick persons should be separately treated, and that there should be no chance that the rapidly changing, and in many instances putrefying substances of one sick body should pass into the bodies of the neighbouring patients. There is, indeed, a continual sacrifice of life from diseases caught in or aggravated by hospitals. The many advantages of hospitals more than counterbalance this sacrifice, but it should be the first object to lessen the chance of injury to the utmost. The risk of transference or aggravation of disease is least in the best-ventilated hospitals. A great supply of air, by immediately diluting and rapidly carrying away the morbid substances evolved in such quantities from the bodies and excretions of the sick, reduces the risk to its minimum, and perhaps removes it altogether. But the supply of air must be enormous; there must be a minimum of not less than 4000 cubic feet per head per hour for ordinary cases; and the supply must be practically unlimited for the acute and febrile diseases.

The causes of the greater contamination of the air of hospitals are these:—

1. More organic effluvia (and, probably, minute organisms) are given off from the bodies and excretions of sick men. These are only removed by the most complete ventilation.

2. The medical and surgical management of the sick necessarily often exposes to the air excretions, dressings, foul poultices, soiled clothes, &c., and the amount of substances thus added to the air is by no means inconsiderable, even with the best management and most complete aseptic treatment.

3. The walls and floors of hospitals absorb organic matters and retain them obstinately, so that in some cases of repeated attacks of hospital

[1] For fuller details, Captain Galton's work on *Hospitals* should be consulted. See also *Five Essays on Hospital Plans, contributed for the Johns Hopkins Hospital Scheme* (Wood and Co., New York); *Report on the Manchester Royal Infirmary*, by J. Netten Radcliffe, Esq.; *Reports on St Mary's Hospital, Paddington*, by F. de Chaumont, M.D.; chapter in Roth and Lex, *Milit. Gesundheitspflege;* paper in the *Practitioner*, March 1877; article "Hospital," *Encyclopædia Britannica*, 9th edition; *Das Allgemeine Krankenhaus der stadt Berlin im Friedrichshain*, von A. Hagemeyer, Berlin, 1879; Degen, *Die Kasernen und Krankenhaüser der Zukunft*, 1883; F. Mouat and Saxon Snell, *On Hospital Construction and Management*, 1883.

gangrene in a ward it has been found necessary to destroy even the whole wall. Continual drippings on the floor of substances which soak into the boards and through crevices, and collect under the floor, also occur, and thus collections exist of putrefying matters which constantly contaminate the air.

4. The bedding and furniture also absorb organic substances, and are a great cause of insalubrity.

5. Till very recently, even in the best hospitals, the water-closets and urinals were badly arranged, and air passed from these places into the wards.

In addition to the amount necessary to dilute and remove these substances, the freest supply of air is also now known to be a curative means of the highest moment; in the cases of the febrile diseases, both specific and symptomatic, it is indeed the first essential of treatment; sometimes, especially in typhus and smallpox, it even lessens duration, and in many cases it renders convalescence shorter.[1]

There can be no doubt that the necessity for an unlimited supply of air is the cardinal consideration in the erection of hospitals, and, in fact, must govern the construction of the buildings. For many diseases, especially the acute, the merest hovels with plenty of air are better than the most costly hospitals without it. It is ill-judged humanity to overcrowd febrile patients into a building, merely because it is called a hospital, when the very fact of the overcrowding lessens or even destroys its usefulness. In times of war, it should never be forgotten by medical officers that the rudest shed, the slightest covering, which will protect from the weather, is better than the easy plan, so often suggested and acted on, of putting the beds a little closer together.

The recognition that the ample supply of pure air is the first essential of a good hospital led Miss Nightingale to advocate with so much energy and success the view which may be embodied in the two following rules :—

1. The sick should be distributed over as large an area as possible, and each sick man should be as far removed as possible from his neighbour.

2. The sick should be placed in small detached and perfectly ventilated buildings, so that there should be no great number of persons in one building, and no possibility of the polluted air of one ward passing into another.

How is this perfect Purity of Air to be secured?

This is a matter partly of construction, partly of superintendence.

(*a*) There should be detached buildings, so disposed as to get the freest air and the greatest light. They should be at considerable distances apart, so that 1000 sick should be spread like a village; and in the wards each man ought to have not less than 100, if possible 120, feet of superficial, and from 1500 to 2000 feet of cubic space. With detached buildings, the size of a hospital, as pointed out by Miss Nightingale, is dependent merely on the facility of administration. When they consist of single buildings the smallest hospitals are the best.

(*b*) The ventilation should be natural, *i.e.*, dependent on the movement of the outer air, and on inequalities of weight of the external and internal air. The reason of this is, that a much more efficient ventilation can be obtained at a cheaper cost than by any artificial means. Also, by means

[1] For examples of the value of a great supply of fresh air on some diseases, see note in former editions of this work.

of open doors and windows, we can obtain at any moment any amount of ventilation in a special ward, whereas local alterations of this kind are not possible in any artificial system. The amount of air, also, which any artificial system can give cheaply is comparatively limited. The amount of air should be restricted only by the necessity of not allowing its movement to be too perceptible.

The best arrangements for natural ventilation for hospitals appear to be these—1*st*, Opposite windows reaching nearly to the ceiling, on the sides of a ward (not wider than 24 to 26 feet, and containing only two rows of beds) and a large end window. 2*nd*, Additional openings, to secure, as far as possible, a vertical movement of the air from below upwards; and this will be best accomplished as follows:[1]—

A tube opening at once to the external air should run transversely along the floor of the ward to each bed, and should end in a box placed under the bed, and provided with openings at the top and sides, which can be more or less closed. In the box, coils of hot-water pipes should be introduced to warm the air when necessary. The area of the tube should not be less than 72 square inches to each bed; and the area of the openings in the box at least four times larger. The fresh air, warmed to any degree, and moistened, if necessary, by placing wet cloths in the box, or medicated by placing chlorine, iodine, or other substances, will then pass under each bed, and ventilate that space so often unaired; and then, ascending round the sides of the bed, will at once dilute and carry up the products of respiration and transpiration to the ceiling. It would be a simple matter so to arrange the hot-water pipes as to be able to cut off all or some of the pipes under a particular bed from the hot-water current if desired, and so to give a fever patient air of any temperature, from cold to hot, desired by the physician. In the low and exhausted stages of fever warm air is often desirable. By this simple plan, we could deal more effectually with the atmosphere round our patients, as to warmth, dryness, humidity, and medication, than by any other. At the same time, the open fire-place and chimney, and the open doors and windows, might be preserved.[2]

For the exit of the foul air, channels in the ridge should be provided, warmed by gas if possible.

To facilitate this system of ventilation, it is desirable to have the buildings one-storied only; but it can be applied with two stories. Only then the discharge tubes must be placed at the sides, and run up in the thickness of the walls.[3]

But not only should there be good ventilation, but the wards ought to be every year empty for two or three weeks, and during the time thoroughly exposed to the air, every door and window being open.

(*c*) The strictest rules should be laid down with regard to the immediate removal from the wards of all excreta, dirty dressings, foul linen, &c.

Nothing that can possibly give off anything to the air should be allowed to remain a single moment. Dressings of foul wounds should be sprinkled with deodorants.

(*d*) The walls should be of impermeable material. Cements of different

[1] A plan similar to this has been devised by Dr S. Hale, and adopted in some of the Australian hospitals. It is an excellent arrangement, but seems rather unnecessarily complicated by taking the air under the floor, and elevating the beds on a dais.

[2] The introduction of vertical tubes is also useful, as giving the air an upward direction, and allowing a considerable supply without draughts.

[3] When the ceiling is flat the outlets may be advantageously placed at the sides close to the ceiling, but with a one-storied or upper ward an open roof is better.

kinds are now used, especially Parian; large slabs of properly coloured tiles, joined by a good cement, and good Portland cement, well painted with indestructible paint, would, however, be better. Parian cracks, and spaces form behind it. Ceilings should be either cemented or frequently lime-

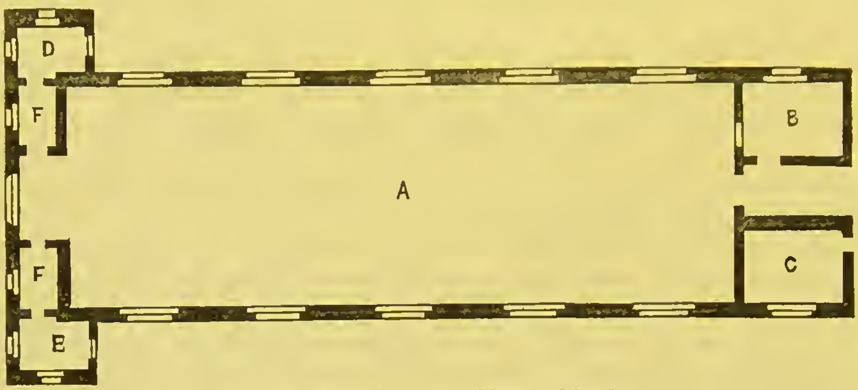

Fig. 38.—Ward for 20 Ward-Beds.

A. Ward.
B. Nurse's room, with Ward Window.
C. Scullery.
D. Water-Closet and Ward Sink.
E. Bath-Room and Ablution Room.
F. Ventilated Lobbies.

washed. Great care should be taken with the floors. On the whole, good oak laid on concrete seems the best material; but the joinings should be perfect, so that no liquid may pass through and collect below the floor. Possibly it might be well to cover the floor with a good oil-cloth, or material of the like kind, which would prevent substances from sinking into the boards, and would lessen the necessity of washing the floors, but might be itself removed, and frequently washed. The practice of waxing and dry-rubbing the floors, and other similar plans, is intended to answer the same purpose. Dr Langstaff, of Southampton, strongly recommended solid paraffin. The paraffin is melted and then poured on the floor, and ironed into it with a box-iron, heated from the interior by burning charcoal; it penetrates about a quarter of an inch into the wood. The excess of paraffin is scraped off, and the floor is brushed with a hard

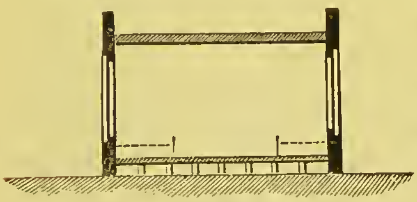

Fig. 39.—Section of Ward to show the Beds.

Fig. 40.—Drawing to show Beds and Windows.

brush; a little paraffin in turpentine is then put on, and the flooring is good for years.[1]

(*e*) The furniture in a ward should be reduced to the minimum; and, as

[1] An experience of some years in the Southampton Infirmary has proved the advantage of this flooring. It has also been introduced with satisfactory results into the Bristol Infirmary, according to information received from Mr Eassie, C.E.

far as possible, everything should be of iron. The bedding should also be reduced in size, as much as it can be. Thick mattresses should be discarded, and thin mattresses, made easy and comfortable by being placed on springs, employed.[1] The material for mattresses should be horse-hair (18 ℔ weight to each mattress), or coir fibre, which, on the whole, are least absorbent. Straw, which absorbs very little, is bulky, and is said to be cold. All flock and woollen mattresses should be discarded. Blankets and coverlets should be white or yellowish in colour, and should be frequently thoroughly aired, fumigated, and washed.

(*f*) The arrangement of the water-closets and urinals is a matter of the greatest moment. Every ward should have a urinal, so that the common practice of retaining urine in the utensils may be discontinued. If the urine is kept for medical inspection, it should be in closed vessels. The removal of excreta must be by water. In hospitals, nothing else can be depended upon, as regards certainty and rapidity. The best arrangement for closets is not the handle and plug, which very feeble patients will not lift; but a bell-pull wire or chain, or a self-acting water supply connected with the door, and flowing when it is open. This plan is better than the self-acting spring seat, which is not always easily depressed by a thin patient; and also, by leaving the door open, it gives us the means of pouring in any quantity of water, and of thoroughly flushing the pan and pipe. The closets are best arranged in nearly detached lobbies at one end of the ward, and separated from it by a thorough cross ventilation, as shown in the plan (fig. 38), which is copied from Miss Nightingale's work.[2] A further improvement may be made by throwing the closets still further out, with an intercepting lobby, as shown in fig. 41. This is the plan adopted in the Cambridge Hospital at Aldershot and in the new station hospitals.

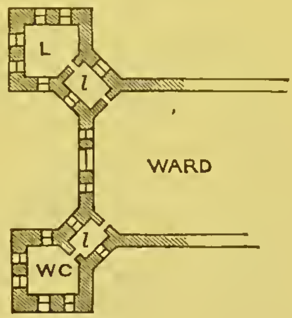

Fig. 41.—Closets (WC) and Lavatory (L) with intervening ventilated Lobbies (*l*).

In this way, provided the site of the hospital is originally well chosen, perfect purity of air can be obtained, and the first requisite of a good hospital is secured.

Next to the supply of pure air, and to the measures for preventing contamination (which embrace construction, ventilation, cleanliness, and latrine arrangements), come the arrangements for medical treatment.

Medical treatment includes—

1. *Supply of Food.*—The diet of the sick is now becoming a matter of scientific precision; and it is probable that every year greater and greater importance will be attached to it. Hence the necessity of a perfect central kitchen, and of means for the rapid supply of food at all times. There is more difficulty in doing this than at first appears, as the central kitchen cannot supply everything; and yet there must be no cooking in the wards, or even near them, as the time of the attendants should be occupied in other ways. Probably the best arrangement is to have hot closets close to

[1] The wire mattress bedstead, as arranged by Dr Reed, in use in the Manchester Royal Infirmary, and made by Messrs Chorlton and Dugdale, seems an excellent and very comfortable form, but there are many others in the market.

[2] Dr Buchanan has suggested a plan of vertical ventilation in the vestibule, in cases where cross ventilation is not available. This, of course, need not to be in a new building, although it might be useful in the adaptation of an existing one. The addition of a slop sink, for the emptying of bed-pans, &c., would also be useful.

the wards, where the food sent from the kitchen can be kept warm, and ready for use at all hours of the day and night.

2. *The Supply of Water.*—Hot and cold water must be supplied everywhere, and baths of all kinds should be available. The supply of water for all purposes should be 40 to 50 gallons per head daily. Many hospitals use much more than this (see under WATER, p. 31).

3. *The Supply of Drugs and Apparatus.*—The chief point is to economise the time of attendants, and to enable drugs and apparatus to be procured without delay when needed.

4. *The Nursing and Attendance, including the Supply of Clean Linen, &c.*—The time and labour of the attendants should be expended, as far as possible, in nursing, and not in other duties. Every contrivance to save labour and cleaning should therefore be employed. Lifts, shafts, tramways, and speaking tubes to economise time; wards arranged so as to allow the attendants a view of every patient; wards not too large or too small, for Miss Nightingale has conclusively shown that wards of from 20 to 32 beds are best suited for economy of service.

5. *Means of Open-Air Exercise for Patients.*—This ought properly to be considered as medical treatment. As soon as a patient can get out of his ward into the open air he should do so; therefore, open verandahs on the sunny sides of the wards, and sheltered gardens, are most important. For the same reason hospitals of one story are best,[1] as the patients easily get out; if of two stories, the stairs should be shallow.

6. In addition to all these, the supply of air medicated with gases, or fine powders, or various amounts of watery vapour, is a mode of treatment which is sure to become more common in certain diseases, and special wards will have to be provided for these remedies.

The parts of a military hospital are[2]—

Patients' Rooms, Wards, and *Day-Rooms,* if possible; the wards of two sizes,—large, *i.e.*, from 20 to 32 beds, and small, for one or two patients. The cubic space per head allowed in temperate climates is 1200 cubic feet, with a floor space of 92 square feet; the air changed twice in the hour.[3] The beds have 7½ feet each running length, or are separated from each other by 3½ feet. It is desirable to have the small wards not close to the large ones, but at some little distance. Attached to the wards are attendants' rooms, scullery, bath and ablution rooms, small store-room, urinal, closets (one seat to every eight men).

Operating Room—Dead-House—Administration.—Surgeons' rooms; case-book and instrument room; offices and officers' rooms.

Pharmacy.—Dispensary; store-room; dispenser's room.

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[1] The late Dr Parkes wrote:—"I had never properly estimated the importance of patients getting into the air, and the desirability of one-storied buildings for this purpose, till I served at Renkioi, in Turkey, during the Crimean war. The hospital was composed of one-storied wooden houses connected by an open corridor. As soon as a man could crawl he always got into the corridor or between the houses, and the good effects were manifest. Some of the medical officers had their patients' beds carried out into the corridor when the men could not walk. In the winter, greatcoats were provided for the men to put on, and they were then encouraged to go into the corridor." In the American hospitals arrangements are made for giving the patients a "sun-bath," that is, getting them out in the air and sunlight as much as possible.

[2] Hospital space is to be provided for 10 per cent. of the force. Lately, since the health of the army has been so much improved on home service, it has been proposed to reduce it to 7 per cent., but it would appear desirable always to have a large hospital space for emergencies and for war. For the duties of administrative medical officers with regard to hospitals, see the *Medical Regulations,* 1885.

[3] In the French army the cubic space allowed is 20 cubic metres (701 cubic feet) for severe cases; 18 cubic metres (631 cubic feet) for ordinary cases, the air changed once in the hour; and the beds, 0·5 metre (18½ inches) apart.

Culinary.—Store-room; wine and beer room; larder and meat room; kitchen; room for arranging diets; scullery; cook's room.

Washing.—Washhouse; dirty-linen store; baking and fumigating room; cleaning room for mattresses.

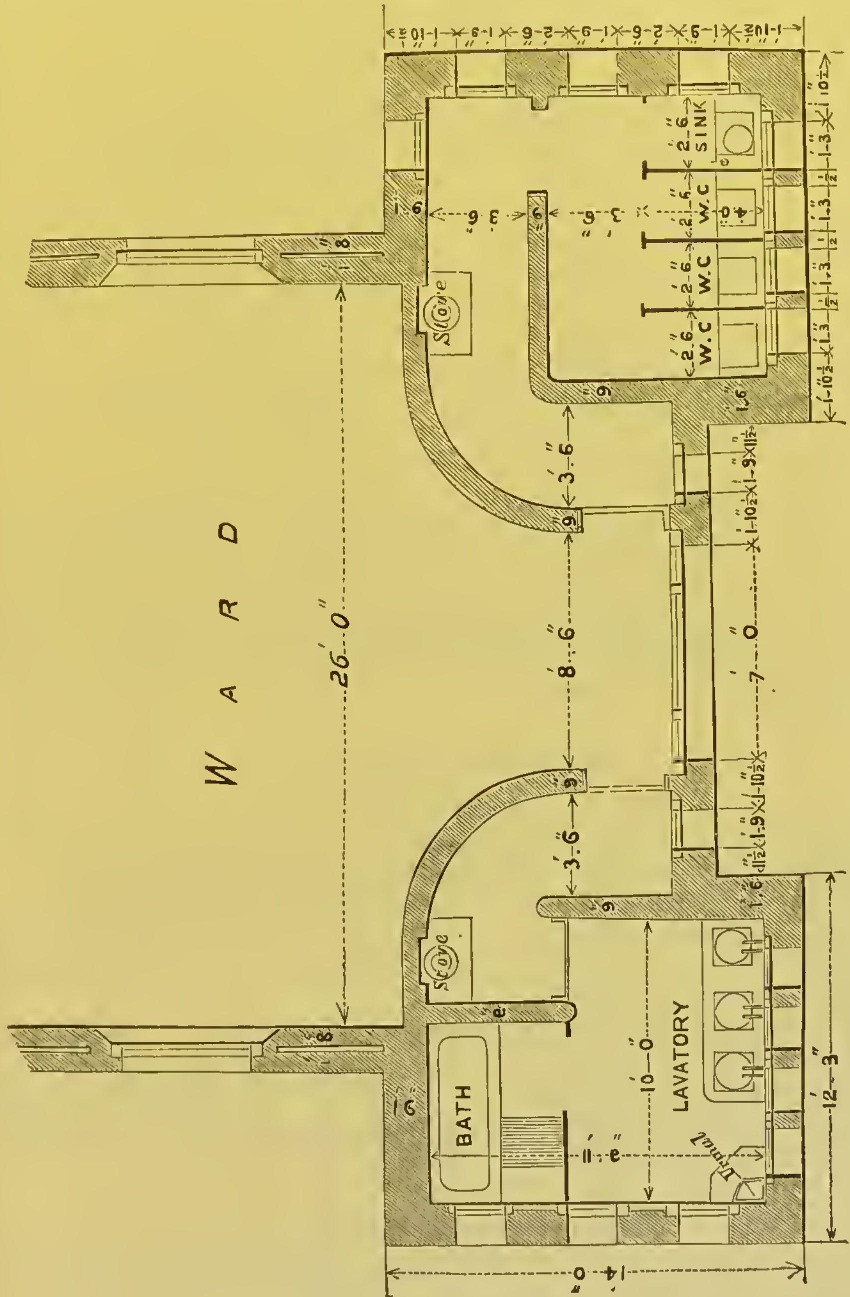

Fig. 42.—Detail of Ward, Lavatory, Closets, and Urinal, as used in Military Hospitals, such as the Herbert Hospital (from Miss Nightingale's book).

Steward's Department.—Offices, furniture, linen, utensil, and pack stores; rooms for cleaning.

The amount for storage room is, for an hospital of 100 sick—

Bedding and store	= 200 square feet.	Fuel store	= 250 square feet.
Clothing store	= 100 ,,	Foul-linen store	= 120 ,,
Utensil store	= 160–200 ,,	Pack store	= 200 ,,
Provision store	= 100 ,,	(In military hospitals.)	

Fig. 42 shows the arrangement of closets and lavatory in a military hospital.

The following plans show the arrangement of the Lariboisière Hospital in Paris,[1] which circumstances have made the type of the so-called block or pavilion plan, and of the Herbert Hospital, which, with the Cambridge Hospital, is the best military hospital in this country, or perhaps anywhere.

The Herbert Hospital at Woolwich consists of four double and three single pavilions of two floors each, all raised on basements. There is a convalescent's day-room in the centre pavilion. The administration is in a separate block in front. The axis of the wards is a little to the east of north. There is a corridor in the basement, through which the food, medicines, coals, &c., are conveyed, and then, by a series of lifts, elevated to the wards. The terraces in the corridor afford easy means of open-air exercise for the patients in the upper ward. The wards are warmed by two central open fire-places, with descending flues, round which are air-passages, so that the entering air is warmed. The floors are iron beams, filled in with concrete, and covered with oak boarding.[2]

The Cambridge Hospital at Aldershot is on much the same plan, but only about half the size (264 patients). The closet and lavatory turrets are thrown out by intervening lobbies (see fig. 41).

The usual shape of ward is oblong, the standard width 26 feet (in the army) to 30 feet (St Thomas's, for instance), and the length being determined by the number of beds. Mr John Marshall[3] has, however, advocated a system of circular wards, which he thinks have certain advantages, and a similar plan has been actually carried out in the new hospital at Antwerp, which is now completed and in occupation.[4] One or two small Military Hospitals in this country, such as the Milton Hospital at Gravesend, are on the circular plan.

Hospitals in the Tropics.

The Barrack and Hospital Commission, in carrying out the plans of the Royal Indian Sanitary Commission, suggest[5] for each sick man—

Superficial area = 100 square feet, up to 120 in unhealthy districts.

Cubical space = 1500 feet, or, in unhealthy districts, 2000 feet.

It is also directed that hospitals should consist of two divisions—1st, for sick; and 2nd, for convalescents. This latter division to hold 25 per cent. of the total hospital inmates.

Each hospital is to be built in blocks, to consist of two floors, the sick and convalescents to sleep on the upper floors only; each block to hold only 20 to 24 beds.

The principles and details are, in fact, identical with those already ordered for the home stations.

Hospitals for Infectious Diseases.

Fever and smallpox hospitals have been long established in many large

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[1] The new Hôtel-Dieu is on the same general plan.

[2] The arrangement of the pavilions may be varied in many ways; for different forms of arrangement, see the works already cited. It has been thought unnecessary to take up space by inserting plans which vary merely in detail.

[3] *On a Circular System of Hospital Wards*, by John Marshall, F.R.S., &c., London, Smith and Elder, 1878.

[4] *British Medical Journal*, Aug. 26, 1882, on p. 350, a ground plan is given; see also *London Medical Record*, July 15, 1881, p. 296; and *Charitable and Parochial Establishments*, by Saxon Snell, F.R.I.B.A., for similar plans; also (by the same author, in conjunction with Dr F. Mouat) *Hospital Construction and Management*, 1883.

[5] *Op. cit.*, p. 27.

English towns; but within the last few years it has become usual for all towns of any size to put up some temporary hospitals during an outbreak

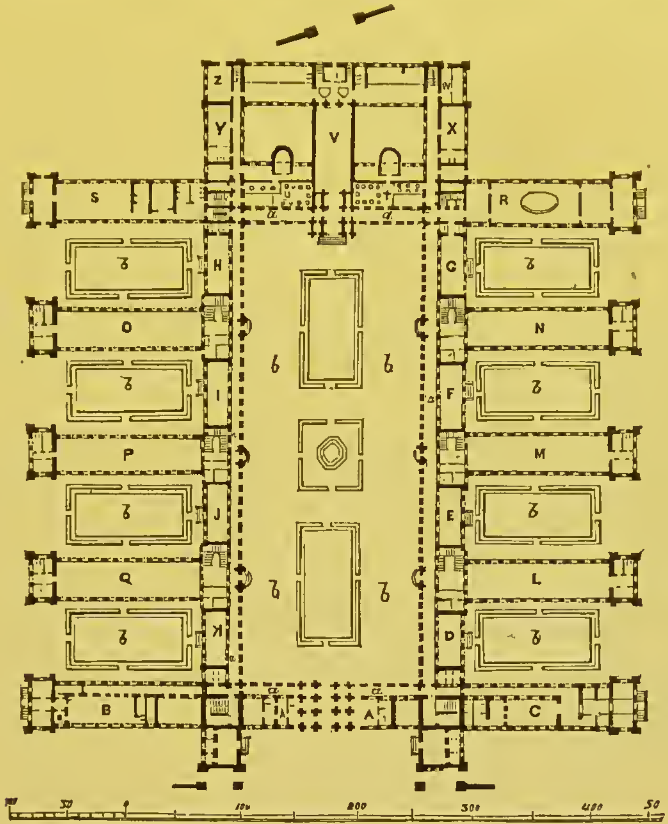

Fig 43.—Lariboisière Hospital at Paris.

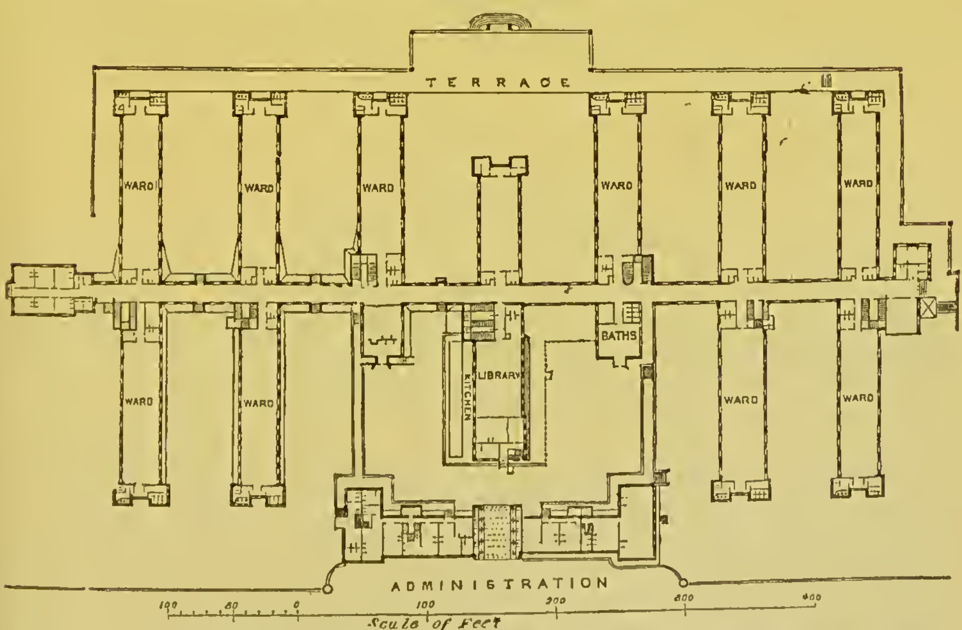

Fig. 44.—Ground Plan of the Herbert Hospital, Woolwich (from Miss Nightingale's book).

of cholera, smallpox, relapsing fever, and typhus, and to remove persons ill with these diseases at once from their dwellings. In this way, if there is

early discovery of the cases, the chances of spread of the disease are greatly lessened.[1]

The Medical Department of the Privy Council issued a Memorandum in 1872,[2] pointing out that power is given under the 37th section of the Sanitary Act, 1866,[3] to the local board, improvement commissioners, town council, or vestry, to provide "hospitals or temporary places for the reception of the sick." It is pointed out that villages should have the means of accommodating instantly four cases of infectious disease in at least two separate rooms, and it is considered that a good cottage would answer this purpose. In towns a permanent provision is advised to be made, and the following suggestions are made:—The situation to be convenient; ward cubic space, 2000 feet per head; ward floor space per head, 144 square feet; good provision for ventilation; precautions against entrance of foul air (as from privies or sinks); warming in winter to 60° Fahr.; keeping cool in summer; means of disposal of excrements and slops; and for cleaning and disinfecting linen.

For temporary emergencies, tents (army hospital marquees) are recommended, or huts are advised. The huts are described at some length, and plans are given of the huts and of the arrangement. As these are very similar to those used by the army in war, reference is made to that section.

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[1] That such hospitals may, however, be themselves centres of infection has been shown by the *Report of the Hospitals Commission*, 1882, which may be consulted for much valuable information.

[2] *Memorandum on Hospital Accommodation to be given by Local Authorities* (signed John Simon, 8th July 1872).

[3] Now under the 131st and following clauses of the *Public Health Act of* 1875.

CHAPTER VII.

WARMING OF HOUSES.

THE heat of the human body can be preserved in two ways—

1. The heat generated in the body, which is continually radiating and being carried away by moving air, can be retained and economised by clothes. If the food be sufficient, and the skin can thus be kept warm, there is no doubt that the body can develop and retain its vigour with little external warmth. In fact, provided the degree of external cold be not too great (when, however, it may act in part by rendering the procuring of food difficult and precarious), it would seem that cold does not imply deficiency of bodily health, for some of the most vigorous races inhabit the cold countries. In temperate climates there is also a general impression that for healthy adults external cold is invigorating, provided food be sufficient, and if the internal warmth of the body is retained by clothing.

2. External heat can be applied to the body either by the heat of the sun (the great fountain of all physical force, and vivifier of life) or by artificial means, and in all cold countries artificial warming of habitations is used.

The points to determine in respect of habitations are—

1*st*, What degree of artificial warmth should be given?

2*nd*, What are the different kinds of warmth, and how are they to be given?

SECTION I.

DEGREE OF WARMTH.

For Healthy Persons.—There appears no doubt that both infants and old persons require much artificial warmth, in addition even to abundant clothes and food. The lowering of the external temperature, especially when rapid, acts very depressingly on the very young and old; and when we remember the extraordinary vivifying effect of warmth, we cannot be surprised at this.

For adult men of the soldier's age, who are properly fed and clothed, it is probable that the degree of temperature of the house is not very material, and that it is chiefly to be regulated by what is comfortable. Any temperature over 48° up to 60° is felt as comfortable, though this is dependent in part on the temperature of the external air. It seems certain that for healthy, well-clothed, and well-fed men we need not give ourselves any great concern about the precise degree of warmth.

For children and aged persons we are not in a position at present to fix any exact temperature; for new-born children a temperature of 65° to 70°,

or even more, may be necessary, and old people bear with benefit a still higher warmth.[1]

For Sick Persons.—The degree of temperature for sick persons is a matter of great importance, which requires more investigation than it has received. There seems a sort of general rule that the air of a sick-room or hospital should be about 60° Fahr., and in most Continental hospitals, warmed artificially, this is the contract temperature; but the propriety of this may be questioned.[2]

There are many diseases greatly benefited by a low temperature, especially all those with preternatural heat. It applies, almost without exception (scarlet fever?) to the febrile cases in the acute stage, that it is desirable to have the temperature of the air as low as 50°, or even 45° or 40°. Cold air moving over the body is a cooling agent of great power, second only, if second, to cold effusion; nor is there danger of bad results if the movement is not too great. The Austrian experiments on tent hospitals[3] show conclusively that even considerable cold is well borne. Even in the acute lung affections this is the case. Pneumonia cases do best in cold wards, provided there is no great current of air over them. Many cases of phthisis bear cool air, and even transitions of temperature, well, provided there be no great movement of air. On the other hand, it would appear that chronic heart diseases with lung congestion, emphysema of the lungs, and diseases of the same class, require a warm air, and perhaps a moist one. With respect to the inflammatory affections of the throat, larynx, and trachea, no decided evidence exists; but the spasmodic affections of both larynx and bronchial tubes seem benefited by warmth.

In the convalescence, also, from acute disease, cold is very badly borne; no doubt the body, after the previous rapid metamorphosis, is in a state very susceptible to cold, and, like the body of the infant, resists external influences badly. Convalescents from fever must therefore be always kept warm. This is probably the reason why it is found inadvisable to tranfer febrile patients treated in a permanent hospital to convalescent tents, although patients treated from the first in tents have a good convalescence in them, as if there was something in habit.

SECTION II.

DIFFERENT KINDS OF WARMTH.

Heat is communicated by radiation, conduction, and convection. The last term is applied to the conveyance from one place to another of heat by means of masses of air, while conduction is the passage of heat from one

[1] It is singular, however, that in some old people the temperature of the body is higher than normal (John Davy). In the case of children we should remember that small bodies have a much larger surface in proportion to bulk than larger bodies. Thus, a sphere of 1 foot in diameter has a solid content of 0·5236 and a surface of 3·1416, or as 1 to 6; whereas a sphere of 2 feet in diameter has a solid content of 4·1888 and a surface of 12·5664, or as 1 to 3; so that the proportion of radiating surface is twice as much in the smaller body.

[2] It is owing to this rule that in French hospitals, artificially ventilated and warmed by hot air, the amount of air is lessened and its temperature heightened in order to keep up the contract temperature of 15° C. (=59° F.). The air is often then close and disagreeable. A safe general rule is never to sacrifice fresh air to temperature, except in the most extreme cases. Of course, cold currents of air are to be avoided if possible, but it is safer, as a rule, to let the general temperature go down rather than diminish the change of air. In most cases it can be compensated for by additional covering.

[3] See Report on Hygiene in the *Army Medical Reports*, vol. iv. by Dr Parkes. The Prussians have also made great use of tents in the summer.

particle to another—a very slow process. Practically, conduction and convection may be both considered under the head of convection.

Radiant heat has been considered by most writers the best means of warming; it heats the body without heating the air,[1] and of course there is no possibility of impurity being added to the air.

The disadvantages of radiant heat are its cost, and its feebleness at any distance. The cost can be lessened by proper arrangement, but the loss of heat by distance is irremediable. The effect lessens as the square of the distance—*i.e.*, if, at 1 foot distance from the fire, the warming effect is said to be equal to 1, at 4 feet distance it will be sixteen times less. A long room, therefore, can never be warmed properly by radiation from one centre of heat only.

It has been attempted to calculate the amount of air warmed by a certain space of incandescent fire, and 1 square inch has been supposed sufficient to warm 8·4 cubic feet of air. But much depends on the walls, and whether the rays fall on them and warm them, and the air passing over them.

Radiating grates should be so disposed as that every ray is thrown out into the room. The rules indicated by Desaguliers were applied by Rumford. Count Rumford made the width of the back of the grate one-third the width of the hearth recess; the sides then sloped out to the front of the recess; the depth of the grate from before backwards was made equal to the width of the back. The sides and back were to be made of non-conducting material; the chimney throat was contracted so as to modify the draught, and insure more complete combustion. The grate was brought as far forward as possible, but still under the throat.

The open chimney, which is a necessity of the use of radiant grates, is so great an advantage that this is *per se* a strong argument for the use of this kind of warming, but, in addition, there can be little doubt that radiant heat is really the healthiest.

Still the immense loss of heat in our common English fire-places must lead to a modification, and radiant heat must be supplemented by

Convection and Conduction.

The air in this case is heated by passing over hot stones, earthenware, iron or copper plates, hot water, steam, or gas pipes. The air in the room is thus heated, or the air taken from outside is warmed, and is then allowed to pass into the room, if possible at or near the floor, so that it may properly mingle with the air already there. The heat of the warming surface should not be great, probably not more than 120° to 140° Fahr.; there should be a large surface feebly heated. The air should not be heated above 75° or 80° Fahr., and a large body of air gently heated should be preferred to a smaller body heated to a greater extent, as more likely to mix thoroughly with the air of the room.

It does not matter what the kind of surface may be, provided it is not too hot. If it is, the air acquires a peculiar smell, and is said to be burnt; this has been conjectured to be from the charring of the organic matter. Some have supposed the smell to be caused by the effect of the hot air on the mucous membrane of the nose, but it is not perceived in air heated by

[1] Dr Sankey has made experiments which show that the temperature of the air of a room heated by radiant heat is really lower than the temperature indicated by the thermometer, because the bulb is warmed by radiation. When this is prevented by enclosing the bulb in a bright tin case the thermometer falls.

the sun. Such air is also relatively very dry, and absorbs water eagerly from all substances which can yield it.

If the air is less heated (not more than 75°) it has no smell, and the relative humidity is not lessened to an appreciable extent. Haller's experiments, carried on over six years with the Meissner stove common in Germany, show that there the relative moisture is not lessened with moderate warming,[1] and the same result has been found with the Galton stoves. On the other hand, when the plates are too hot, the air may be really too much dried, and Dr Sankey states that, while he never found the difference between the dry and wet bulbs in a room warmed by radiant heat to be more than 8° Fahr., he has noticed in rooms warmed by hot air a difference of 15° to 17° Fahr., which implies a relative humidity, if the temperature be 60°, of only 34 per cent. of saturation, which is much too dry for health. In this case the air is always unpleasant, and must be moistened by passing over water before it enters the room, if possible; some heat is thus lost, but not much. Of the various means of heating, water is the best, as it is more under control, and the heat can be carried everywhere. Steam is equally good, if waste steam can be utilised, but if not, it is more expensive. Hot water pipes are of two kinds: pipes in which the water is not heated above 200° Fahr., and which, therefore, are not subjected to great pressure; and pipes in which the water is heated to 300° or 350° Fahr., and which are therefore subjected to great pressure. These pipes (Perkin's patent) are of small internal calibre (about ½ inch), with thick walls made of two pieces of welded iron; the ends of the pipes are joined by an ingeniously contrived screw. In the low pressure pipes there is a boiler from which the water circulates through the pipes and returns again, outlets being provided at the highest points for the exit of the air. In Perkin's system there is no boiler; one portion of the tube passes through the fire.

Mr Hood states that 5 feet of a 4-inch pipe will warm 1000 cubic feet in a public room to 55°. In dwelling-houses, for every 1000 cubic feet 12 feet of 4-inch pipe should be given, and will warm to 65°. In shops, 10 feet, and in workrooms 6 feet, per 1000 cubic feet are sufficient. If Perkin's pipes are used, as the heating power is greater, a less amount does, probably about two-thirds, or a little more.[2]

Steam piping is now also much used, and in some cases is more convenient even than water. The Houses of Parliament are warmed by steam pipes in a chamber under the floor; the radiating surface of the pipes is increased by soldering on to them at intervals a number of zinc or (preferably) small copper plates. If it is wished to lessen the amount of heat, the pipes, where provided with thin plates, are simply covered with a woollen cloth.

The easy storing up and conveyance of heat to any part of the room or house by means of water pipes, the moderate temperature, and the facility of admission of external air at any point by passing the fresh air over coils, or water leaves, make it certain that the plan of warming by hot water will be greatly used in time to come, although the open fire-place may be retained for comfort.

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[1] *Die Lüftung und Erwärmung der Kinderstube und des Krankenzimmers*, von D. C. Haller, 1860, pp. 29–38.

[2] The following formula will give the length of pipe required:—Let t' = temperature to be obtained in the room, t the temperature of the external air, d' the cubic feet of air to be warmed per minute, T the temperature of the pipes, Δ the external diameter of the pipe, and L the length of pipe required, then:—

$$\frac{2{\cdot}252\, d'(t'-t)}{\Delta(T-t')} = L.$$

Mr George has devised a gas stove (called the Calorigen) which appears to be a decided improvement on the common gas stove. Gas is burnt in a small iron box, and the products of combustion are carried to the open air by a tube. Another coiled tube runs up through the box; this communicates below with the outer air, and above opens into the rooms. As the fresh air passes through this tube it is warmed by the heat of the gas stove. Mr Eassie speaks very well of this stove, which he has put up in several places. He says he has known one to be persistently capable of registering fifteen degrees above the external temperature during a very severe winter, and that too in a room of over 1700 cubic feet, with the roof and three sides constructed of glass.[1] A coal calorigen is also made which seems to answer well. Dr F. T. Bond's euthermic stove is also a very good contrivance.

A plan which was proposed 130 years ago by Desaguliers is now coming into general use, viz., to have an air-chamber round the back and sides of a radiating grate, and to pass the external air through it into the room. Thus a great economy of heat, and a considerable quantity of gently warmed air, passes into the room. In Sir D. Galton's grate, and in the plan proposed by Mr Chadwick for cottages, the lower part of the chimney is also made use of. The advantages of these grates are that they combine a good amount of cheerful open fire, radiant heat, and chimney ventilation, with supplementary warming by hot air, so that more value is obtained from the fuel, and larger spaces can be more effectually warmed. A great number of patents have been taken out for grates of this kind. The air-chamber should not be too small, or the air is unduly heated; the heated surface should be very large; fireclay sometimes gives a peculiar odour to the air, which iron does not do if the surface of iron be very large and disposed in gills; a combination also of iron and fireclay is said to be good, and to give no odour. The conduit leading to the air-chamber should be short, and both it and the chamber should be able to be opened and cleaned, as much dust gets in. The room opening of the air-chamber should be so far up that the hot air may not be at once breathed, and there should be no chance of its being at once drawn up the chimney. The action of all stoves of the kind is liable to considerable variation from the action of the wind; and sometimes the current is even reversed and hot air is driven out.

Attention has been directed both in France and America to the fact of the comparative ease with which gases pass through red-hot cast-iron. Mr Graham showed that iron heated to redness will absorb 4·15 times its volume of carbon monoxide; and the experiments by MM. Deville and Troost, made at the request of General Morin, proved that in a cast-iron stove heated with common coal there passed through the metal in 92 hours 589 c.c. of carbon monoxide,[2] or from ·0141 to ·132 per cent. of the air which was slowly passed over the hot surface. In America Dr Derby [3] has directed particular attention to this point, and has adduced very strong reasons for believing that the decidedly injurious effects produced by some of the plans of warming houses, especially by air passing over a cast-iron furnace heated with anthracite, is due to an admixture of carbon monoxide. Professor Coulier of the Val de Grâce [4] contended that the amount of carbon monoxide passing through in the experiments of Deville and Troost was really so small, that if mixed with the air of a room which is fairly ventilated, it would be

[1] *Sanitary Arrangements for Dwellings*, 1874, p. 140.
[2] *Comptes Rendus de l'Acad.*, Jan. 1868. These experiments were first undertaken in consequence of a statement by Dr Carret, that in the department of Haute-Savoie an epidemic occurred which affected persons only in the houses where iron stoves were, and not porcelain.
[3] *Anthracite and Health*, by G. Derby, M.D., Professor of Hygiene in Harvard University.
[4] *Mem. de Med. Mil.*, Sept. 1868, p. 250.

quite innocuous; and he believes (from direct experiment) that the headache and oppressive feeling produced by these iron stoves are really owing, as was formerly believed, to the relative dryness of the air. But evidence is adverse to this now. The gas passes with much greater difficulty through wrought-iron, or through stoves lined with fireclay.[1]

A great number of grates and stoves have been proposed, which it is impossible here to notice. In Germany many excellent stoves are now used, which not only economise fuel but warm the outside air, which is admitted round or under them.[2] The medical officer's advice will be sought, first, as to the kind; and, second, as to the amount of heat. He will find no difficulty in coming to the conclusion that in most cases both methods (radiation and convection) should be employed; the air warmed by plates or coils of water pipes being taken fresh from the external air and thereby conducing to ventilation. He will also be called on to state the relative amount of radiant and convected heat, and to determine the heat of the plates, and of the air coming off them, and the degree of humidity of the air. The thermometer, and the dry and wet bulbs, will give him all the information he wants on these points.[3]

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1 Dr Bond has recommended a coating of silicate as a preventive against the passage of deleterious products through an iron stove.

2 See a good account in Roth and Lex's work (*op. cit.*, p. 365).

3 Mr Chadwick has called attention to the old Roman plan of the Hypocaust, where the floor of the room is warmed by pipes, or by carrying smoke-flues under it, and he has contrived some ingenious plans to carry out the idea. There can be no doubt of the great comfort of this plan, although it appears to be expensive. Attention has also been called to heating on the *whole house* system, and there can be no doubt that this is an excellent plan, if properly carried out and carefully supervised. Drs Drysdale and Hayward in this country (*Health and Comfort in House Building*, London, 1872), and Dr Griscom of New York, have devised ingenious plans for the purpose. In colder countries, such as Russia, the plan is in general use, but apparently with little or no regard to proper supply of fresh air or carrying away of foul air.

CHAPTER VIII.

FOOD.

SECTION I.

GENERAL PRINCIPLES OF DIET.

In the widest acceptation of the term, Food includes everything ingested, which goes directly or indirectly to the growth or repair of the body or to the production of energy in any form. In this way it would include not only those organic and mineral solids and the usual beverages recognised as dietetic, but also water and air. For it is quite obvious that without water no function of the living body would be possible, whilst the production of energy is mainly, if not entirely, caused by the union of the atmospheric oxygen with the organic matter of the food or the tissues of the body itself. Although these facts are distinctly recognised, it has generally been the practice to restrict the term "food" to those substances which are capable of oxidation and those which act as directors or regulators of nutrition, to the exclusion of air and water,—these two last being usually considered under separate heads. No one group even of this rough classification is capable of sustaining healthy life alone, and a combination of all, or nearly all, the different constituents of diet is required to accomplish the best results. It is also necessary to limit the application, "food," so as to exclude generally medicines and poisons, which, on the one hand, either act or are intended to act upon processes of unhealthy nutrition, or, on the other hand, prevent the processes of healthy nutrition, and so induce unhealthy nutrition and ultimately dissolution. Even here the line cannot be too strictly drawn, for in many cases it is a question more of quantity than kind that determines the direction of the action.

The enumeration and classification of the foods or aliments necessary to maintain human life in its most perfect state have been usually based on the deduction of Prout that milk contains all the necessary aliments and in the best form. The substances in milk are—1st, the nitrogenous matters, viz., the casein principally, and, in smaller quantities, albumin, lacto-protein, and perhaps other albuminous bodies; 2nd, the fat and oil; 3rd, sugar in the form of lactin; 4th, water and salts, the latter being especially combinations of magnesium, calcium, potassium, sodium, and iron, with chlorine, phosphoric acid, and, in smaller quantities, sulphuric acid.

In addition to their occurrence in milk, which is admitted to be a perfect food for the young, this enumeration of aliments appears to be justified by two considerations. First, that the different members of each class, *inter se*, have a remarkably similar composition, while there are broad lines of physical and chemical demarcation between the classes; and secondly, that the different classes appear to serve different purposes in nutrition, and are all necessary for perfect health.

The first point, the similarity of composition among the different mem-

bers of the same class, is obvious enough. The nitrogenous aliments are blood-fibrin, muscle-fibrin or syntonin, myosin, vegetable fibrin, albumin in its various forms, casein (in its animal and vegetable forms), and globulin. Their composition, &c., are remarkably uniform; they contain between 15·4 and 16·5 per cent. of nitrogen, and may be conveniently distinguished by the common term of albuminoids. They can replace each other in nutrition, and are for the most part included under the head of "digestible albuminoids"; these are converted into peptones in the process of digestion. In all digestible nitrogenous food a certain amount of peptone is to be found, and the artificial conversion of the albuminoids into peptonised food is of great advantage in cases of weakened digestion. But care must be taken not to overdo this, so as to deprive the digestive organs of the exercise of their proper functions. There are some other nitrogenous bodies, such as gelatin and chondrin, and the substances classed under keratin or elastin, which, though approaching in chemical characters to the other substances, are not their nutritive equals. There are still other nitrogenous substances, such as the extractives contained in the juice of the flesh; these, although not actual flesh-formers, appear to be essential to nutrition as regulators and stimulants to digestion, particularly when gelatine and bodies of that kind form a part of a diet.

The second class (sometimes called hydro-carbons) consists of the various animal and vegetable fats, wax, &c., the composition of which is very uniform, and the chief nutritive differences of which depend on physical conditions of form or aggregation, which conditions cause some fats, when acted upon by the alimentary fluids, to be more easily absorbed than others.

The group of the starchy and saccharine substances (the carbo-hydrates), or of their allies or derivatives (dextrin, pectin), is equally well characterised by chemical resemblances, *inter se*, and differences from the other groups. The several dietetic starches, sugars, including lactin, cellulose (whose want of nutritive power is dependent on form and aggregation, and which requires for digestion a more elaborate apparatus than some animals possess), and the various derivatives of the starches, are all closely allied. There has been some doubt whether pectin should be classed chemically with the sugar and starch group, as the oxygen and hydrogen are not in the proportions to form water, but this is perhaps no objection to its association in a dietetic classification.

The fourth class, consisting of the salts already noted and of water, needs no comment.

The physiological evidence that these classes of aliments serve different purposes in nutrition is not so complete as that of their chemical differences.

A broad distinction must, of course, be drawn between the nitrogenous and non-nitrogenous substances. Modern researches, which have much modified our opinion of the direction in which the potential energy of the dietetic principles may be manifested (as heat, or electricity, or mechanical movement), and of the mode in which the nitrogenous substances, in particular, aid or restrain this transformation, do not impeach the proposition that the presence of nitrogen in an organised structure, and its participation in the action going on there, is a necessary condition for the manifestation of any energy or any chemical change. Whether, when energy is manifested, the nitrogenous framework of any nitrogenous structure is a mere stage on which other actors play, or whether it is used up and destroyed, or is, on the other hand, built up or renovated during action, is, so far as classification of food is concerned, a matter of no consequence.

The following considerations seem to prove the necessary participation of the nitrogenous structures in manifestations of energy. Every structure in the body in which any form of energy is manifested (heat, mechanical motion, chemical or electrical action, &c.) is nitrogenous. The nerves, the muscles, the gland cells, the floating cells in the various liquids, the semen and the ovarian cells, are all nitrogenous. Even the non-cellular liquids passing out into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen, in order that these actions shall be performed; and the same constancy of the presence of nitrogen, when function is performed, is apparently traceable through the whole world. Surely such constancy proves necessity. Then, if the nitrogen be cut off from the body, the various functions languish. This does not occur at once, for every body contains a store of nitrogen, but it is at length inevitable. Again, if it is wished to increase the manifestation of the energies of the various organs, more nitrogen must be supplied. The experiments of Pettenkofer and Voit show that the nitrogenous substances composing the textures of the body determine the absorption of oxygen.[1] The condensation of the oxygen from the atmosphere, its conversion into its active condition (ozone), and its application to oxidation are, according to their experiments, entirely under the control of the nitrogenous tissues (fixed and floating), and are apparently proportional to their size and vigour,[2] and to changes occurring in them. The absorption of oxygen does not determine the changes in the tissues, but the changes in the tissues determine the absorption of oxygen. In other words, without the participation of the nitrogenous bodies, no oxidation and no manifestation of energy is possible. The experiments show that the absorption of oxygen by the lungs (blood-composition and physical conditions of pressure, &c., remaining constant) is dependent on its disposal in the body, and that this disposal is in direct relation with the absolute and relative amount and action of the nitrogenous structures. Mechanical motion, electricity, or heat may be owing to oxidation of fat or of starch, or of nitrogenous substance; but, whatever be the final source, the direction is given by the nitrogenous structures.

The next point is not quite so clear. Are the non-nitrogenous bodies, the fats and the starches, to be again broadly separated into two groups, which cannot replace each other; or, are these nutritively convertible? It is now certain that fat may arise from albuminoids, so that the nitrogenous substance plays two parts—first, that of the organic framework, *i.e.*, of the regulator of oxidation and of transformation of energy; and, second, it may form a non-nitrogenous substance which is oxidised and transformed.

The experiments of Edward Smith, Fick and Wislicenus, Haughton, and others, on muscular action, prove that we must look for the main source of energy which is apparent during muscular action in the oxidation of non-nitrogenous substances, but no experiments have yet shown whether these are fatty or saccharine. It seems to be inferred that it is fat which is thus chiefly acted upon; but this opinion is rather derived from a reference to the universal presence of fat when energy is manifested, to the known necessity of it in diet (for though the dog and the rat (Savory) can live on

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[1] *Zeitsch. für Biologie*, Band ii. p. 457. See, especially, the summary of their opinion at page 571.

[2] When to a diet of meat, which causes a certain absorption of oxygen, fat or sugar is added, the absorption of oxygen lessens (Ranke, *Phys. des Menschen*, 1868, p. 145); so that it is relative as well as absolute amount which comes into play.

fat-free meat alone, man cannot do so),[1] and from the large amount of energy its oxidatiou can produce, than from actual observation. If it were true, a broad distinction would be at once drawn between fatty and starchy food, but it is not experimentally proved. If, on the other hand, it were certain that the starchy aliments formed fat in the human body as a rule, this would be a reason for drawing no distinction between the groups. Independent of the argument drawn from bees fed on sugar alone and forming wax, from the fattening of ducks and geese, and the older experiments on pigs, the later experiments of Lawes and Gilbert[2] seem to show clearly that the fat stored up in fattened pigs cannot be derived from the fat given in the food, but must have been produced partly from nitrogenous substances, but chiefly from the carbo-hydrates. So also it seems now probable that the fat in milk is not derived at once from blood, but from changes of albumin in the lacteal gland-cells. There seems no reason why we should not extend the inference to man. If so, a man could live in perfect health on a diet composed only of fat-free meat and starch, with salts and water, just as he can certainly live (though perhaps not in the highest health) on meat, fat, salts, and water. The carbo-hydrates would then be proved to be able to replace fats. The experiment has not yet been performed, or at least recorded, but it seems important it should be.

Grouven's experiments also suggest that in cattle the carbo-hydrates may split up in the alimentary canal into glycerine, lactic and butyric acids, aud carbon dioxide aud marsh gas. If this be true, in the herbivora the starches would be merely another form of fat.

An argument against the fats and carbo-hydrates being mutually replaceable under ordinary conditions in the diet of men is drawn from a consideration of the diets used by all nations. In no case in which it can be obtained is an admixture of starch, in some form, with fat omitted. Moreover, in all cases (except in those natious, like the Eskimos, who are under particular conditions of food), we find that the amount of fat taken is comparatively small as compared with that of starches. The fats when taken into the body enter like the albuminoids into the structure of the tissues,[3] of which fat forms in probably all cases an essential part. The carbo-hydrates, on the other hand, in the human body do not appear to be parts of the tissues, though they are contained in the fluids which bathe them, or are contained in them. The special direction which the chemical changes in the carbo-hydrates take in the body seems also to point to special duties. Thus, the formation of lactic and other acids of the same class must arise from carbo-hydrates chiefly or solely. But the formation of these acids is certainly most important in nutrition, for the various reactions of the fluids, which offer so striking a contrast (the alkalinity of the blood, the acidity of most mucous secretions, of the sweat, urine, &c.), must be chiefly owing to the action of lactic acid on the phosphates, or the chlorides, and to the ease with which it is oxidised aud removed. If the

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[1] Ranke could not maintain himself in perfect nutrition on meat alone.—*Physiol. des Menschen*, 1868, p. 149.

[2] "On the Sources of the Fat in the Animal Body," *Phil. Mag.*, Dec. 1866.

[3] The fats appear to pass into the body directly and after saponification, which renders absorption easy. The soap is then, according to Radziejewski's experiments (Virchow's *Archiv*, Band xliii. p. 268), reconverted into fat. It has been supposed that the greater part of the tissue fat (fat cells) is not derived in this way, but from the tissue albuminoids; but Hofmann's experiments and reasonings (*Zeitsch. für Biol.*, Band viii. p. 153) seem to show that the ingested fats are stored up largely. Clinical observations certainly support this view.

direction of the changes which the carbo-hydrates undergo within the body is different from that of the fats, the products of these changes must be inferred to play dissimilar parts.

Without pushing these arguments too far, and with the admission that the subject is still obscure, we are fairly entitled to assert that the two groups of fats and carbo-hydrates are not so immediately and completely convertible as to permit us to place them together in a classification of diets.

In the second question to which reference has been made, viz., that of a nitrogenous substance furnishing fat, or a carbo-hydrate, the case is simpler. The experiments of Voit, and of Lawes and Gilbert, as well as other considerations, prove that the fat of tissues may be derived from nitrogenous substances, and there are reasons to believe that a glycogenous substance may also be derived from albuminoids.[1] It is also probable, though not proved, that these non-nitrogenous derivatives may be burnt up in the muscles and other parts, as Fick conjectures.[2] But this cannot allow us to consider an albuminoid as an aliment which may replace fat or starch in the case of man. The digestive system of man is framed so differently from that of the carnivora that fat must be taken in its own form, for it either cannot be formed in sufficient quantity from albuminoids, or the body is poisoned by the excess of nitrogen which is necessarily absorbed to supply it.

With regard to the necessity of all four classes of aliments, it can be affirmed with certainty that (putting scurvy out of the question) men can live for some time and can be healthy with a diet of albuminoids, fat, salts, and water. But special conditions of life, such as great exercise, or exposure to very low temperature, appear to be necessary, and under usual conditions of life health is not very perfectly maintained on such diet. It has not yet been shown that men can live in good health on albuminoids, carbo-hydrates, salts, and water, &c., without fat.[3]

The exact effect produced by the deprivation of any one of these classes is not yet known. An excess of the albuminoids causes a more rapid oxidation of fat (and in dogs an elimination of water), while an excess of fat lessens the absorption of oxygen, and hinders the metamorphosis of both fat and albuminoid tissues. The carbo-hydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

It is now generally admitted that the success of Mr Banting's treatment of obesity is owing to two actions: the increased oxidising effect on fat, consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of the starches.

Health cannot be maintained on albuminoids, salts, and water alone; but, on the other hand, it cannot be maintained without them.

The salts and water are as essential as the nitrogenous substanees. Lime, chiefly in the form of phosphate, is absent from no tissue; and there is reason to think no cell growth can go on without it; certainly, in enlarging morbid growths, and in rapidly growing cells, it is in large amount.

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[1] In addition to physiological evidence from experiments on animals, there are certain forms of diabetes which seem to prove that sugar must be formed either from albuminoids or fat, most probably the former.

[2] *Archiv. für ges. Phys.*, Band v. p. 40.

[3] In some experiments, both with Liebig's essence of meat and Hassall's dried food with bread, Dr Parkes was very much struck with the bad effects produced on the health of the experimentators, and with the immediate relief given by the addition of butter and a larger supply of starch, without augmentation in the amount of nitrogen.

When phosphate of calcium was excluded from the diet, the bones of an adult goat were not found by H. Weiske to be poorer in lime,[1] because probably lime was drawn from other parts; but the goat became weak and dull, so that nutrition was interfered with. Experiment has shown that the growth of wheat is more quickly and effectually checked by the absence of phosphoric acid than of any other constituent from the soil. The lowest forms of life (*Bacteria* and *Fungi*) will not grow without earthy phosphates.

Magnesia is probably also an essential constituent of growth in some tissues. Potash and soda, in the forms of phosphates and chlorides, are equally important, and would seem to be especially concerned in the molecular currents; forming parts of almost all tissues, they are less fixed, so to speak, than the magnesian and lime salts. It is also now certain, that the two alkalies do not replace each other, and have a different distribution; and it is so far observable, that the potash seems to be the alkali for the formed tissues, such as the blood cells or muscular fibre; while the soda salts are more largely contained in the intercellular fluids which bathe or encircle the tissues.

The chlorine and phosphoric acid have also very peculiar properties,—the former apparently being easily set free, and then giving a very strong acid, which has a special action on albuminoids, and the latter having remarkable combining proportions with alkalies. Both are furnished in almost all food; the sodium chloride also separately. Carbonic acid is both introduced and made in the system, and probably serves many uses. Iron is, of course, also essential for certain tissues or parts, especially for the red blood corpuscles and for the colouring matter in muscle, and in small quantity is found almost in every tissue and in every food. The sulphur and phosphorus of the tissues appear to enter especially as such with the albuminoids.

Some salts, especially those which form carbonates in the system, such as the lactates, tartrates, citrates, and acetates, give the alkalinity to the system which seems so necessary to the integrity of the molecular currents. The state of malnutrition, which in its highest degree we call scurvy, appears to follow inevitably on their absence; and, as they exist chiefly in fresh vegetables, it is a well-known rule in dietetics to supply these with great care, though their nutritive power otherwise is small. So important are those substances, that they might well be placed in a separate class, although Dr Pavy remarks that " these principles are hardly of sufficient importance, in an alimentary point of view, to call for their consideration under a distinct head." Surely this is an under-estimate of their importance, considering the inevitable malnutrition that follows on their absence.

In addition to the substances composing these four classes, there are others which enter into many diets, and which have been termed " accessory foods," or by some writers " force regulators " (like the salts). The various condiments which give taste to food, or excite salivary or alimentary secretions, and tea, coffee, cocoa, alcohol, &c., furnish the chief substances of this class. Much discussion has taken place as to the exact action in nutrition of these substances, but little is definitely known.

A classification, on a simplified plan, may be made as follows :—

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[1] *Zeitsch. für Biol.*, Band vii. p. 179.

		Examples.	Functions.
Nitrogenous.	1. *Albuminoids.* All substances containing nitrogen, of a composition identical with, or nearly that of albumin; proportion of nitrogen to carbon being nearly as 2 to 7, or 4 to 14.	Animal. Albumin, Fibrin, Syntonin, Myosin, Globulin, Casein, Vegetable. Glutin, Legumin,	Formation and repair of tissues and fluids of the body. Regulation of the absorption and utilisation of oxygen. May also form fat and yield energy under special conditions. In most foods the above, both animal and vegetable, are partially converted into peptones.
	*** Substances containing a larger proportion of nitrogen are apparently less nutritious. Proportion of nitrogen to carbon about 2 to 5½, or 4 to 11.	Gelatin, Ossein, Chondrin, Keratin,	These perform the above functions less perfectly, or only under particular circumstances.
	Extractive matters, such as are contained in the juice of the flesh.		These substances appear essential as regulators of digestion and assimilation, especially with reference to the gelatine group.
Non-nitrogenous substances.	2. *Fats* (or Hydro-carbons). Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the proportion of oxygen being *less* than sufficient to convert all the hydrogen into water. Proportion of unoxidised hydrogen to carbon about 1 to 7.	Olein, Stearin, Margarin,	Supply of fatty tissues; nutrition of nervous system? Supply of energy and animal heat by oxidation.
	3. *Carbo-hydrates.* Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being exactly sufficient to convert all the hydrogen into water. Proportion of water to carbon being about 3 to 2.	Starch, Dextrin, Cane sugar, Grape sugar, Lactin (or milk sugar),	Production of energy and animal heat by oxidation. Conversion into fat by deoxidation.
	3 (*a*). *Vegetable acids* (*and pectous substances*?). Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being generally in greater amount than is sufficient to convert all the hydrogen into water.	Oxalic acid, Tartaric ,, Citric ,, Malic ,, — In these the oxygen is *more* than sufficient to convert all the hydrogen into water. Acetic ,, Lactic ,, — In these there is no excess of oxygen.	Preserving the alkalinity of the blood by conversion into carbonates; furnish a small amount of energy or animal heat by oxidation.
Mineral.	4. *Salts* (mineral).	Sodium chloride, Potassium ,, Calcium phosphate, Magnesium ,, Iron, &c.	Various: support of bony skeleton, supply of HCl for digestion, &c. Regulators of energy and nutrition.

Sub-Section I.—Quantity of each Class of Proximate Aliment in a Good Diet for Healthy Men.

We cannot deduce these quantities from milk, for this, though it is a perfect food for the young, does not contain the various constituents in the best proportions for adults. The relative amounts have, therefore, been determined partly by observation on a great number of dietaries, and partly

by physiological experiments. The general results of the whole are given in the following tables :—

Average Daily Diet of Men in Quietude.

	Subsistence Diet (Playfair).		Rest.	
	Ounces Avoir.	Grammes.	Ounces Avoir.	Grammes.
Albuminoids, . . .	2	57	2·5	71
Fats, ...	·5	14	1	28
Carbo-hydrates, . .	12	340	12	340
Salts, ...	·5	14	·5	14
Total water-free food,	15·0	425	16·0	453

The *subsistence* diet is calculated as sufficient for the internal mechanical work of the body, but it is doubtful if an average man could exist on it without losing weight, as it supposes absolute repose.

The diet for *rest* supposes very gentle exertion, and is probably the minimum for a male adult of average size and weight, say 150 ℔ or 68 kilogrammes.

Each constituent named above is, theoretically, absolutely water-free, but practically the amount of water present in the so-called solid food would be from 100 to 150 per cent. more, so that the weights respectively would be about 32 to 40 ounces gross (907 to 1134 grammes).

For mere subsistence, without doing visible work, a man therefore requires about $\frac{1}{10}$ of an ounce of water-free food for each ℔ weight of his body, or about $\frac{1}{150}$ of his total weight every twenty-four hours.

Of the standard diets given in the next table, Moleschott's scale has been pretty generally accepted, but the fat is perhaps rather low.

Standard Daily Diets for a Man in Ordinary Work, weighing 150 *lbs., or* 68 *kilogrammes.*

	For 300 foot-tons, or 93,000 kilogramme-metres.						For 100,000 kilog.-metres =323 foot-tons.	
	Moleschott.		Pettenkofer and Voit.[1]		Ranke.[2]		Moleschott.	
	Oz. av.	Gram.	Oz. av.	Gram.	Oz. av.	Gram.	Oz. av.	Gram.
Albuminoids, . .	4·59	130	4·83	137	3·52	100	4·94	140
Fats, ...	2·96	84	4·12	117	3·52	100	3·17	90
Carbo-hydrates, . .	14·26	404	12·40	352	8·46	240	15·31	434
Salts, ...	1·06	30	1·06	30	0·89	25	1·13	32
Total water-free food,	22·87	648	22·41	636	16·39	465	24·55	696

Assuming the water-free food to be 23 ounces, and a man's weight to be

1 *Zeitschrift für Biologie,* Band ii. p. 523. Somewhat different quantities are given by Voit in his later researches made with Forster, Renk, and Schuster (Munich, 1877), the fat during work being much increased. See Flügge, *Lehrbuch der hygienischen Untersuchungsmethoden,* Leipzig, 1881.

2 *Physiologie des Menschen,* 1868, p. 158.

150 lb, each lb weight of the body receives in twenty-four hours 0·15 ounce, or the whole body receives nearly $\frac{1}{100}$ part of its own weight.

This is the dry food, but a certain amount of water (between 50 and 60 per cent. usually) is contained in ordinary food, and adding this to the water-free solids, the total daily amount of so-called dry food (exclusive of liquids) is about 48 to 60 ounces. In addition to this, from 50 to 80 ounces of water are taken in some liquid form, making a total supply of water of 70 to 90 ounces, or an average of 0·5 ounce for each lb weight of body.

This average amount of food and water varies considerably from the following causes :—

1. Individual conditions of size, vigour, activity of circulation, and of the eliminating organs, &c. No men eat exactly the same, and no single standard will meet all cases.[1] The usual average range in different male adults is from 40 to 60 ounces of so-called solid food, and from 50 to 80 ounces of water.

2. Differences of exertion. If men are undergoing great exertion they take more food, and, if they can obtain it, the increase is especially in the classes of albuminoids and fat, as shown in the next table below.

This would represent of so-called solid food from 66 to 77 oz. (1870 to 2180 grammes).

The amount of water is also increased, but is very various according to circumstances, and is apparently not so much augmented as the solid food.

3. Differences of climate. It is a matter of general belief that more food is taken in cold seasons and in cold countries than in hot. It is supposed that more energy in some form (finally in that of heat) is necessary, and more food is required; but there may be other causes, such as varying exertion.

Average Daily Water-free Diet required for an Adult Man in very laborious Work,[2] or for a Soldier on Service and in the Field.

	Ounces Avoir.	Grammes.
Albuminoids, . . .	6 to 7	170 to 198
Fats, ...	3·5 to 4·5	99 to 128
Carbo-hydrates, . .	16 to 18	454 to 510
Salts, ...	1·2 to 1·5	34 to 43
Total water-free food,	26·7 to 31·0	757 to 879

[1] This has been well exemplified in our convict prisons, in which, as a matter of convenience, soldiers are sometimes confined. The ordinary diet, which is sufficient for the convict, is insufficient for the soldier, and that for several reasons :—1. The convict is a smaller man on the average. 2. The previous life of the convict is an irregular one, in which his food is generally insufficient; whereas the soldier's life is usually the opposite, his food is fairly good and his meals regular. 3. The crimes for which the convict is imprisoned are crimes against society, and his removal to a prison cannot be considered much of a degradation morally, whereas his physical condition is really improved. On the other hand, the soldier's crime is often one of a military character only, hence his removal to a prison is a moral degradation, especially if it be a convict prison. The result is that, whilst the majority of the civil prisoners retain their weight or even gain, the majority of soldier prisoners lose. It is also found that age has an effect, the older men losing, the younger generally gaining. Length of sentence has also an influence, partly on account of some difference of diet and work, but probably chiefly on account of the system ultimately accommodating itself to the altered conditions. Thus the men who lose weight are—the heaviest originally, the oldest, those with shortest sentences; those who are stationary or gain weight are—the lightest originally, the youngest, those with longest sentences. The data, from which the above conclusions are drawn, were furnished by Deputy-Surgeon-General J. A. Marston, M.D.

[2] Playfair gives the diet of a prize-fighter in training as 9·8 oz. albuminoids, 3·1 fats, and 3·27 starch and sugar. There were 690 grains of nitrogen, and 4366 grains of carbon.

The following may be taken as an approximative basis for the calculation of diets according to size and work :—

Proximate Aliment.	For Subsistence during rest.		For work of about 300 foot-tons per diem.		For work of about 100,000 kilog.-metres per diem, =323 foot-tons.	
	Ounces Avoir. per lb of body-weight.	Grammes per kilogramme of body-weight.	Ounces Avoir. per lb of body-weight.	Amount to be added to subsistence diet per lb of body for every foot-ton of work. Ounces Avoir.	Grammes per kilogramme of body-weight.	Amount to be added to subsistence diet per kilogr. of body-weight for every 1000 kilog.-metres of work. Grammes.
Albuminoids,	0·017	1·044	0·031	0·00005	2·06	0·010
Fats, . .	0·007	0·412	0·019	0·00004	1·32	0·009
Carbo-hydrates,	0·080	5·000	0·095	0·00005	6·38	0·014
Salts, . .	0·003	0·163	0·007	0·00001	0·47	0·003
Total,	0·107	6·619	0·152	0·00015	10·23	0·036

Beyond 300 to 320 foot-tons (or 100,000 kilogramme-metres) the addition would require to be greater.

Proximate Aliment.	For work of 450 to 500 foot-tons per diem.		For work of about 150,000 kilogramme-metres per diem. =foot-tons per diem.	
	Ounces Avoir. per lb of body-weight.	Amount to be added to ordinary work diet per lb of body-weight for every foot-ton of work beyond 300.	Grammes per kilogramme of body-weight.	Amount to be added to ordinary work diet per kilogramme of body-weight for every 1000 kilog.-metres beyond 100,000.
Albuminoids, .	0·047	0·000107	2·91	0·017
Fats, . . .	0·030	0·000068	1·88	0·011
Carbo-hydrates, .	0·120	0·000166	7·50	0·024
Salts, . . .	0·010	0·000020	0·63	0·003
Total, .	0·207	0·000361	12·92	0·055

In the case of any diet, the articles of which are known, the amounts of the four classes of alimentary principles may be calculated from a table of mean composition. The following table is compiled from, in most cases, several analyses by different authors, those analyses being selected which seem best to represent the food of the soldier. [1]

The mode of using the table is very simple; the quantity of uncooked meat or bread being known, and it being assumed or proved that there is no loss in cooking, a rule of three brings out at once the proportions. Thus, the ration allowance of meat for soldiers being 12 oz., 2·4 oz. or 20 per cent. is deducted for bone, as the soldier does not get the best parts. The quantity of water in the remaining 9·6 ounces will be $\frac{75 \times 9{\cdot}6}{100} = 7{\cdot}2$,

[1] Of course, such tables are merely approximative; but they are very useful as giving a general idea of a diet, although they are not accurate enough to be used in physiological inquiries.

Table for Calculating Diets.[1]

Articles.	In 100 Parts.				
	Water.	Albuminoids.	Fats.	Carbohydrates.	Salts.
Meat of best quality, with little fat, like beafsteaks,	74·4	20·5	3·5	...	1·6
Uncooked meat of the kind supplied to soldiers,[1]—beef and mutton. Bone constitutes ⅕th of the soldier's allowance,	75	15	8·4	...	1·6
Uncooked meat of fattened cattle. Calculated from Lawes' and Gilbert's experiments. These numbers are to be used if the meat is very fat,	63	14	19	...	3·7
Cooked meat,[2] roast, no dripping being lost. Boiled assumed to be the same,	54	27·6	15·45	...	2·95
Corned beef (Chicago),	52·2	23·3	14	...	4
Salt beef (Girardin),	49·1	29·6	0·2	...	21·1
,, pork (Girardin),	44·1	26·1	7·0	...	22·8
Fat pork (Letheby),	39·0	9·8	48·9	...	2·3
Dried bacon (Letheby),	15·0	8·8	73·3	...	2·9
Smoked ham (J. König),	27·8	24·0	36·5	...	10·1
Horse flesh (do.),	·74·3	21·7	2·6	...	1·0
White fish (Letheby),	78·0	18·1	2·9	...	1·0
Poultry (Letheby),	74·0	21·0	3·8	...	1·2
Bread, white wheaten, of average quality,	40	8	1·5	49·2	1·3
Wheat flour, average quality,[3]	15	11	2	70·3	1·7
Barley meal (de Chaumont),	11·3	12·7	2·0	71·0	3·0
Pearl barley (Church),	14·7	7·3	1·1	75·8	1·0
Rye (mean of various analysts),	13·5	13·1	2·0	69·3	2·1
Biscuit,	8	15·6	1·3	73·4	1·7
Rice,	10	5	0·8	83·2	0·5
Oatmeal (Letheby),	15	12·6	5·6	63·0	3
Maize (Poggiale) (cellulose excluded),	13·5	10	6·7	64·5	1·4
Macaroni (König),	13·1	9·0	0·3	76·8	0·8
Millet (König) (cellulose excluded),	12·3	11·3	3·6	67·3	2·3
Arrow-root,	15·4	0·8	...	83·3	0·27
Peas (dry),	15	22	2	53	2·4
Potatoes,	74	2·0	0·16	21·0	1
Carrots (cellulose excluded),	85	1·6	0·25	8·4	1·0
Cabbage,	91	1·8	0·5	5·8	0·7
Butter,	6	3·3	88	...	variable, taken as 2·7
Egg (10 per cent. must be deducted for shell from the weight of the egg),	73·5	13·5	11·6	...	1
Cheese,	36·8	33·5	24·3	...	5·4
Milk (sp. gr. 1029 and over),	86·8	4	3·7	4·8	0 7
Cream (Letheby),	66	2·7	26·7	2·8	1·8
Skimmed milk (Letheby),	88	4·0	1·8	5·4	0·8
Sugar,	3	...	...	96·5	0·5
Pemmican (de Chaumont),	7·2	35·4	55·2	...	1·8

and the water-free solids will be 2·4 ounces. The albuminoids will be 1·44 ounces; the fats, 0·8064; and the salts, 0·1536 ounce.

Whenever practicable, the nutritive value should be calculated on the raw substance, as the analyses of cooked food are more variable. It must then be seen that no loss occurs in cooking.

[1] For remarks, see separate sub-sections.
[2] These numbers are taken from John Ranke's analysis.
[3] The fat and salts may be 40 to 60 per cent. less in finely sifted flour.

The proportion of the nitrogenous substances to the fats, carbo-hydrates, and salts in the standard diets is as follows :—

	Moleschott.	Pettenkofer and Voit.	Ranke.	Mean.
Albuminoids, . .	100	100	100	100
Fat, ...	65	87	100	82
Carbo-hydrates, . .	315	258	240	272
Salts, ...	23	22	25	23

Amount of Nitrogen and Carbon.—As the phenomena of nutrition are chiefly owing to the various chemical interchanges of nitrogen and carbon, and in some cases of hydrogen, with oxygen, it may be desired to calculate the amount of these constituents in any diet. This may be done in two ways.

1. Calculate out the dry albuminoids, fat, and carbo-hydrates in ounces, and then use the following table :—

Water-free constituents.	Nitrogen.	Carbon.	Hydrogen.	Sulphur.
	Grains.	Grains.	Grains.	Grains.
Albuminoid : 1 ounce contains .	70	212	8	6
Fat, ,, ,, .	...	336	48	...
Carbo-hydrates,				
(*a*) Starch, ,, ,, .	...	194	...	...
(*b*) Cane-sugar, ,, .	...	184	...	...
(*c*) { Lactin, Glucose, } ,, .	...	175	...	...

The total amount of carbon in one ounce of albuminoid is 233 grains, but of this 30 grains are converted into urea, and are therefore oxidised only as far as carbon monoxide; making allowance for this, we have a net total equal to 212 grains of carbon fully oxidised.

The standard daily diet for an adult man in ordinary work, calculated in this way, assuming the composition from the table on p. 243, gives—

	Moleschott.	Pettenkofer and Voit.	Ranke.	Mean.
	Grains.	Grains.	Grains.	Grains.
Nitrogen, ...	321	338	246	302
Carbon, ...	4737	4817	4570	4708
Hydrogen, . . .	179	236	197	204
Sulphur, ...	28	29	21	26
Salts, ...	464	464	390	430

Not infrequently the standard is stated as 20 grammes of nitrogen and 300 grammes of carbon ; this is equal to 309 and 4630 grains.

2. In the following table, the calculation of these ingredients per ounce has been made,—the substance being supposed to be in its natural state, and to have the composition already assigned to it in the former table.

Substance.	One ounce (=437·5 grains) contains in its natural state, in grains.					
	Water.	Nitrogen.	Carbon, capable of being oxidised.	Hydrogen, capable of being oxidised.	Sulphur, capable of being oxidised.	Salts.
Uncooked meat (beef) of the best quality,	326	14·3	55	3·2	1·2	7
Uncooked meat as supplied to soldiers,	328	10·5	60	5·2	0·9	7
Uncooked fat meat (beef),	276	9·8	94	10·2	0·8	16
Cooked meat,	236	19·3	110	9·6	1·7	13
Corned beef (Chicago),	228	16·3	96	8·6	1·4	17
Salt beef,	215	20·7	63	2·5	1·8	92
,, pork,	193	18·3	79	5·4	1·6	100
Fat pork,	170	6·9	185	24·3	0·6	10
Dried bacon,	66	6·2	265	39·9	0·5	12
Smoked ham,	122	16·8	174	19·4	1·4	44
Horse flesh,	325	15·2	55	2·9	1·3	4
White fish,	341	12·6	48	2·8	1·1	4
Poultry,	324	14·7	57	3·5	1·3	5
Bread,	175	5·5	116	1·3	0·5	6
Wheat flour,	66	7·7	166	1·9	0·7	7
Barley meal,	49	8·9	173	2·1	0·8	13
Pearl barley,	64	5·1	167	1·1	0·4	4
Rye,	59	9·2	168	2·0	0·8	9
Biscuit,	35	10·9	180	1·8	0·9	7
Rice,	44	3·5	175	0·8	0·3	2
Oatmeal,	66	8·8	168	3·7	0·8	13
Maize,	59	7·0	169	4·0	0·6	6
Macaroni,	57	6·3	169	0·9	0·5	3
Millet,	54	7·9	166	2·6	0·7	10
Arrow-root,	57	0·6	162	0·1	...	1
Peas (dried),	66	15·4	156	2·8	1·3	10
Potatoes,	324	1·4	45	0·3	0·1	4
Carrots,	372	1·1	20	0·2	0·1	4
Cabbage,	398	1·3	17	0·3	0·1	3
Butter,	26	2·3	303	42·5	0·2	12
Eggs,	322	9·4	68	6·7	0·8	4
Cheese,	161	23·5	153	14·4	2·1	24
Milk (sp. gr. 1029 and over),	380	2·8	30	2·1	0·2	3
Cream,	289	1·9	100	13·0	0·2	8
Skimmed milk,	385	2·8	24	1·2	0·2	3
Sugar,	13	...	178	...	...	2
Pemmican,	31	24·8	260	29·8	2·1	8

The usual range is from 250 to 350 grains of nitrogen for adult men, and the extreme range is from 2 to 7 ounces of dry albuminoid, or from 140 grains of nitrogen (which is the smallest amount necessary for the inner movements of the body and the bare maintenance of life, as calculated by Playfair), to 483 or 500 grains, which is the amount taken under very great exertion. Edward Smith's careful observations on ill-fed and fairly-fed operatives give a range from 135 grains of nitrogen and 3271 grains of carbon (in London needlewomen) to 349 grains of nitrogen and 6195 grains of carbon (in Irish farm labourers). Usually, however, in what are almost starvation diets, the nitrogen is 180 to 200 grains, and the carbon from 3900 to 4300 grains (Edward Smith's investigations into the food in Lancashire during the cotton famine). In convict prisons, Dr Wilson tells us that the men on light labour receive 224 grains of nitrogen and 4651 grains of carbon, and this is sufficient. Those on hard labour receive 255 grains of nitrogen and 5289 grains of carbon, and on this diet

they lose weight, and have to be continuously shifted from heavy to lighter work. In the case of military prisoners at hard labour even 281 grains of nitrogen and 5373 grains of carbon were insufficient to prevent men losing weight. In India an improved diet was introduced by the late Surgeon-General Beatson, C.B., in which the nitrogen was about 300 grains and the carbon about 5300. This appears to have been sufficient to prevent loss of weight, although there was a deficiency of fat. The carbon ranges in various diets from 3600 to 5800 or 6000 grains. The amount of the salts appears rather large; it is difficult to test it by determining the salts in the excreta, as so much sodium chloride and lime salts are lost through the skin, and some of the excreted salts may also be mere surplusage. The salts seem to be made up of chlorine, 120 grains; phosphoric acid, 50 grains; potash, 40; soda, 40; lime, about 4 grains by the urine (Byasson) and some by the bowels; magnesia, 4·7 grains by the urine and a considerable amount by the bowels; and iron, the amount of which is uncertain.

Actual experiment has, to a great extent, confirmed the conclusions drawn from a study of these dietaries. Pettenkofer and Voit, in two healthy men, determined many times the amount of nitrogen during common exercise, and found it to be 19·82 grammes, or 306 grains. Dr Parkes experimented on four healthy average men in common work, and found the amount which kept them in perfect health and uniform weight was 293 to 305 grains of nitrogen in twenty-four hours. All these determinations are near Moleschott's numbers. The amount of carbon is, however, perhaps too large. A certain proportion between the carbon and nitrogen ought to be maintained; in the best diets this is: Nitrogen 1 to carbon 15.[1]

SUB-SECTION II.—ON THE ENERGY OBTAINABLE FROM THE VARIOUS ARTICLES OF FOOD.

The possible amount of energy which can be manifested in the body will be the result of two conditions,—first, the amount of potential energy stored up in the food, which is, of course, easily determined and expressed in terms of units of heat or of motion; and second, the extent to which the processes in the body can liberate and apply this energy. For example, an ounce of albumen can give rise to a certain heating effect, if it be burnt in oxygen; but in the body thorough oxidation can never occur, for some of the constituents of the albumen pass out incompletely oxidised in the form of urea. An ounce of sugar, on the other hand, is as a general rule destroyed to the fullest extent, and ends in carbon dioxide and water, and its actual energy in the body, under whatever form it appears, is equal to its theoretical energy.

One ounce of dry albuminoid yields . .	173	foot-tons of potential energy.
,, ,, fat, ...	378	,, ,,
,, ,, starch, ...	138	,, ,,
,, ,, cane-sugar, . . .	131	,, ,,
,, ,, lactin or glucose, . .	124	,, ,,
One grain of carbon (converted into CO_2),	0·710	,, ,,
,, hydrogen (water), . .	3·000	,, ,,
,, sulphur (SO_2), . . .	0·205	,, ,,
,, phosphorus (P_2O_5), . .	0·510	,, ,,
,, carbon (forming urea), . .	0·198	,, ,,
One cubic foot of carbonic acid (CO_2) at 0° C. shows	168	foot-tons expended.
One ounce of water (H_2O) shows . .	146	,, ,,

[1] "The Soldier's Ration," by F. de Chaumont, *Sanitary Record*, Feb. 5, 1876.

In the following table (page 248) Dr Frankland's experimental results have been selected as the most exact, but they agree very closely with the theoretical results, particularly with those given by Playfair[1] and others. Some of the numbers are calculated from the ascertained composition of the substance.

A table of this kind is useful in showing what can be obtained from our food, but it must not be supposed that the value of food is in exact relation to the possible energy which it can furnish. In order that the energy shall be obtained, the food must not only be digested and taken into the body properly prepared, but its energy must be developed at the place and in the manner proper for nutrition. The mere expression of potential energy cannot fix dietetic value, which may be dependent on conditions in the body unknown to us. For example, it is quite certain, from observation, that gelatine cannot fully take the place of albumen, though its potential energy is little inferior,[2] and it is easily oxidised in the body. But, owing to some circumstances yet unknown, gelatine is chiefly destroyed in the blood (?) and gland cells, and its energy, therefore, has a different direction from that of albumen. The tables of energy give broad indications, and can be used in a general statement of the value of a diet; but at present they do not throw light on the intricacies of nutrition.

Sub-Section III.—On the Relative Value of Food of the same Class.

The chemical composition of animal and vegetable albuminoids is very similar, and they manifestly serve equal purposes in the body. The meat-eater, and the man who lives on corn, or peas and rice, are equally well nourished. But it has been supposed that either the kind or the rapidity of nutrition is different, and that the man who feeds on meat, or the carnivorous animal, will be more active, and more able to exert a sudden violent effort, than the vegetarian, or the herbivorous animal, whose food has an equal potential energy, but which is supposed to be less easily evolved. The evidence in favour of this view seems very imperfect. The rapid movements of the carnivora have been contrasted with the slow, dull action of domestic cattle; but, not to speak of the horse, who, that has seen the lightning movements of the wild antelope or cow, or even of the wild pig, which is herbivorous in many cases, can doubt that vegetable feeders can exert a movement even more rapid and more enduring than the tiger or the wolf? And the evidence in men is the same. In India, the ill-fed people, on rice and a little millet or pea, may indeed show less power; but take the well-fed corn eater, or even the well-fed rice and pea eater, and he will show, when in training, no inferiority to the meat-eaters. An argument has been drawn from the complicated alimentary canal of the herbivora, but probably this is chiefly useful in digesting the cellulose, and the digestion and absorption of albuminoids may be as rapid as in other animals.

It appears from Dr Beaumont's experiments that animal food is digested sooner than farinaceous, and possibly meat might therefore replace more quickly the wasted nitrogenous tissue than bread or peas; and it may be

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[1] *On the Food of Man in relation to his useful Work*, 1865.

[2] One gramme of dry isinglass will develop 4520 heat-units when burnt in oxygen; one gramme of dry boiled ham, 4343; one gramme of dry beef, 5313 heat-units (Frankland, *Philos. Mag.*, Sept. 1866, p. 169). The potential energy of isinglass is more than that of ham, but its nutritive power is far inferior.

N.B.—To convert *foot-tons per ounce* into *kilogramme-metres per gramme*, multiply by 10·92. Thus, *one ounce* of albuminoid yields 173 *foot-tons* of potential energy, then *one gramme* will yield $173 \times 10{\cdot}92 = 1889$ *kilogramme-metres*.

true, as asserted, that the change of tissue is more quick in meat-eaters, who require, therefore, more frequent supplies of food. Even this, however, seems not yet thoroughly proved.

Energy developed by one ounce of the following Substances when oxidised in the Body.

Name of Substance.	In usual state, with the same percentage of water as in the table on p. 243.	One ounce, water-free.
	Foot-tons.	Foot-tons.
Beef, uncooked, best quality (beefsteaks),	49	191
Meat ,, as supplied to soldiers, .	58	232
Beef ,, fattened, . . .	96	260
Meat, cooked, ...	106	231
Corned beef (Chicago), ...	93	194
Salt beef, ...	52	102
Salt pork, ...	71	127
Fat pork, ...	202	331
Dried bacon, ...	292	344
Smoked ham, ...	179	248
Horse flesh, ...	48	187
White fish, ...	42	191
Poultry, ...	50	192
Bread, ...	88	147
Wheat flour, ...	124	146
Biscuit, ...	133	144
Rice, ...	127	141
Oatmeal, ...	130	153
Barley meal, ...	127	144
Pearl barley, ...	122	143
Rye, ...	126	146
Maize, ...	131	162
Macaroni, ...	124	142
Millet, ...	126	144
Arrowroot, ...	116	136
Peas (dried), ...	119	140
Potatoes, ...	33	127
Carrots, ...	16	107
Cabbage, ...	13	144
Butter, ...	339	361
Eggs, ...	68	257
Cheese, ...	150	237
Milk (cow's), new, ...	27	205
Cream, ...	109	321
Skimmed milk, ...	21	175
Sugar, ...	126	130
Pemmican, ...	270	293
Ale (Bass's bottled), ...	30	260
Stout (Guinness's), ...	42	360

It has been also supposed that there is a difference in the nutrition of even such nearly allied substances as wheat and barley, but the evidence is imperfect, and is perhaps dependent on differences in ease of digestion.

With respect to the fats, their differences of nutrition are probably dependent entirely on facility of digestion and absorption. The animal fats appear easier of absorption than the vegetable. Berthé[1] found that, in addition to the fat in his ordinary diet, he could absorb 30 grammes, or

[1] *Ludwig's Phys.*, Band ii. p. 668.

1·06 ounces of cod-liver oil, butter, or other animal oil; in some instances 1¾ ounces were absorbed. Of vegetable oils only 20 grammes, or 0·7 ounce, were absorbed. When, in experiments with cod-liver oil, 40 grammes were taken, 31·5 were absorbed, 8·5 passed by the bowels; when 60 grammes were taken, 48 were absorbed and 12 passed. But when he took 60 grammes daily, the amount of fat in the fæces gradually increased, until 50 grammes daily passed off in that way. In the dog, however, Bischoff and Voit found that 250 and 300 grammes (8·8 and 10·6 ounces) of butter were easily absorbed. During the digestion of the fats they are, probably, in part decomposed; and the fatty acids, like the acids derived from the starch, must, to a certain extent, antagonise the introduction of alkali in the food.

The various carbo-hydrates are generally supposed to be of equal value. Starch requires a little more preparation by the digestive fluids than grape sugar, into which it appears first to pass; but the change is so rapid that it can hardly be made a point of difference between them. It is observable, however, that even when sugar is cheap and accessible, it is not used to replace starch entirely; but this, perhaps, may be a matter of taste.

SUB-SECTION IV.—THE DIGESTIBILITY OF FOOD.

In order that food shall be digested and absorbed, two conditions are necessary: the food must be in a fit state to be digested, and it must meet in the alimentary canal with the chemical and physical conditions which can digest and absorb it.

Fitness for digestibility depends partly on the original nature of the substance, as to hardness and cohesion, or chemical nature, and partly on the manner in which it can be altered by cooking. Tables of degree of digestibility have been formed by several writers, and especially by Dr Beaumont, by direct experiment on Alexis St Martin; but it must be remembered that these are merely approximative, as it is so difficult to keep the conditions of cooking equal.[1]

Rice, tripe, whipped eggs, sago, tapioca, barley, boiled milk, raw eggs, lamb, parsnips, roasted and baked potatoes, and fricasseed chicken are the most easily digested substances in the order here given,—the rice disappearing from the stomach in one hour, and the fricasseed chicken in 2¾ hours. Beef, pork, mutton, oysters, butter, bread, veal, boiled and roasted fowls, are rather less digestible,—roast beef disappearing from the stomach in three hours, and roast fowl in four hours. Salt beef and pork disappeared in 4¼ hours.[2]

As a rule, Beaumont found animal food digested sooner than farinaceous, and in proportion to its minuteness of division and tenderness of fibre.

The admixture of the different classes of foods aids digestibility; thus fat taken with meat aids the digestion of the meat; some of the accessory foods probably increase the outpour of saliva, gastric or enteric juice, &c.

The degree of fineness and division of food; the amount of solidity and of trituration which should be left to the teeth, in order that the fluids of the mouth and salivary glands may flow out in due proportion; the bulk of the food which should be taken at once, are points seemingly slight, but of real importance. There is another matter which appears to affect digestibility, viz., variety of food.

[1] The preparation of food by cooking is so important a matter, that the art of cookery ought not to be considered as merely the domain of the gourmand. Health is greatly influenced by it, and it is really a subject to be practically studied by chemists and physiologists.

[2] An extended table is given in Cox's excellent edition of Combe's *Physiology of Digestion*, p. 123.

According to the best writers on diet, it is not enough to give the proximate dietetic substances in proper amount. Variety must be introduced into the food, and different substances of the same class must be alternately employed. It may appear singular that this should be necessary; and certainly many men, and most animals, have perfect health on a very uniform diet. Yet there appears no doubt of the good effects of variety, and its action is probably on primary digestion. Sameness cloys; and with variety more food is taken, and a larger amount of nutriment is introduced. It is impossible, with rations, to introduce any great variety of food; but the same object appears to be secured by having a variety of cooking.[1] In the case of children, especially, a great improvement in health takes place when variety of cooking is introduced; and by this plan (among others), Dr Balfour succeeded marvellously in improving the health of the boys in the Duke of York's school.

The internal conditions of abundance and proper composition of the alimentary fluids, and the action of the muscular fibres in moving the food, so that it shall be submitted to them, depend on the perfection of the nervous currents, the vigour of circulation, and the composition of the blood. Many of the digestive diseases the physician has to treat depend on alterations in these conditions, so that the food is only imperfectly digested. Experiments, by Plôsz, Maly, and Gyergyai, seem to show the value of converting the albuminoids into peptones by artificial digestion, so as to aid the digestion of the sick.[2] Many excellent preparations are now in the market (see page 310).

In framing diets, it is well to remember that almost every article has some portion which is more or less indigestible, but which is generally included in the calculation of its proximate or ultimate constituents. The proportion thus unutilised varies, but it ranges on an average from 5 to 10 per cent. Elaborate tables are given by Flügge[3] and Meinert.[4]

SECTION II.

DISEASES CONNECTED WITH FOOD.

So great is the influence of food on health, that some writers have reduced hygiene almost to a branch of dietetics. Happiness, as well as health, is considered to be insured or imperilled by a good or improper diet, and high moral considerations are supposed to be involved in the due performance of digestion. If there is some exaggeration in this, there is much truth; and doubtless, of all the agencies which affect nutrition, this is the most important.

The diseases connected with food form, probably, the most numerous order which proceeds from a single class of causes; and so important are they, that a review of them is equivalent to a discussion on diseases of nutrition generally.

It is of course impossible to do more here than outline so large a topic. Diseases may be produced by alterations (excess or deficiency) in quantity; by imperfect conditions of digestibility, and by special characters of quality.

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1 On this subject see Meinert's *Massen-Ernährung*, Berlin, 1885.

2 "Ueber Peptone," *Archiv für die Ges. Phys.*, Band ix. p. 323.

3 *Untersuchungen*, &c., p. 424.

4 *Armee- und Volks-Ernährung*, Berlin, 1880, vol. i. pp. 129–131, in which he quotes from Rubner (*Zeitschr. f. Biologie*, xv. u. xvi.) and Voit.

Sub-Section I.—Alterations in Quantity.

1. *Excess of Food.*—In some cases, food is taken in such excess that it is not absorbed; it then undergoes chemical changes in the alimentary canal, and at last putrefies; quantities of gas (carbon dioxide, carburetted hydrogen, and hydrogen sulphide) are formed. As much as 30 ℔ of a half-putrid mass have been got rid of by purgatives.[1] Dyspepsia, constipation, and irritation, causing diarrhœa which does not always empty the bowels, are produced, sometimes some of the putrid substances are absorbed, as there are signs of evident poisoning of the blood, a febrile condition, torpor and heaviness, fœtor of the breath, and sometimes possibly even jaundice. It was, no doubt, cases of this kind which led to the routine practice of giving purgatives; and as this condition, in a moderate degree, is not uncommon, the use of purgatives will probably never be discontinued.

The excess of food may be absorbed. The amount of absorption of the different alimentary principles is not precisely known. Dogs can digest an immense quantity of meat, and especially if they are fed often, and not simply largely once or twice a day. In men, also, much meat and albuminous matter can be digested,[2] though it is by no means uncommon, in large meat-eaters, to find much muscular fibre in the fæces. Still, enough can be taken, not merely to give a large excess of nitrogen, but even to supply carbon in sufficient quantity for the wants of the system.

There is certainly a limit to the digestion of starch (though sugar, however, is absorbed in large amount), as after a very large meal much starch passes unaltered. This is also the case with fat. But in all cases habit probably much affects the degree of digestive power; and the continued use of certain articles of diet leads to an increased formation of the fluids which digest them.

When excess of albuminoids continually passes into the system, congestions and enlargements of the liver, and probably other organs, and a general state of plethora, are produced. If exercise is not taken at the same time, there is a disproportion between the absorbed oxygen and the absorbed albuminoids, which must lead to imperfect oxidation, and therefore to retention in the body of some substances, or to irritation of the eliminating organs by the passage through them of products less highly elaborated than those they are adapted to remove.

Although not completely proved, it is highly probable that gouty affections arise partly in this way, partly probably from the use of liquids which delay metamorphosis, and therefore lead to the same result as increased ingestion, and in some degree also from the use of indigestible articles of food.

Very often large meat-eaters are not gouty, and do not appear in any way over-fed. In this case either a great amount of exercise is taken, or, as is often the case in these persons, the meat is not absorbed, owing frequently to imperfect mastication.

A great excess of albuminoids, without other food, produces, in a short time (five days—Hammond), marked febrile symptoms, malaise, and diarrhœa; and, if persevered in, albumen appears in the urine. Ranke has attributed the depression especially to the effect of the salts of the meat.

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[1] A good case of this kind is recorded by Routh (*Fæcal Fermentation*, p. 19). Some convicts in Australia received from $7\frac{1}{4}$ to $7\frac{1}{2}$ ℔ of food daily. Obstinate constipation, dyspepsia, diarrhœa, skin diseases, and ophthalmia were produced. Purgatives brought away large quantities of half-putrid masses.

[2] Jones's and especially Hammond's experiments, *Experimental Researches*, 1857, p. 20.

Excess of starches and of fats delays the metamorphosis of the nitrogenous tissues, and produces excess of fat. Sometimes acidity and flatulence are caused by the use of much starch. It is not understood if profounder diseases follow the excessive use of starches, unless decided corpulence is produced, when the muscular fibres of the heart and of many voluntary muscles lessen in size, and the consequences of enfeebled heart's action occur. When an excessive quantity of starch is used to replace albuminoids, in physiological experiments, the condition becomes of course a complex one.

If an excess of starch be taken under any circumstances, much passes into the fæces, and the urine often becomes saccharine.

There may be also excess of food in a given time,—that is, meals too frequently repeated, though the absolute quantity in twenty-four hours may not be too great.

2. *Deficiency of Food.*—The long catalogue of effects produced by famine is but too well known, and it is unnecessary to repeat it here. But the effects produced by deficiency in any one of the four great classes of aliments, the other classes being in normal amount, have not yet been perfectly studied.

The complete deprivation of albuminoids, without lessening of the other classes, produces marked effects only after some days. In a strong man kept only on fat and starch, Dr Parkes found full vigour preserved for five days; in a man in whom the amount of nitrogen was reduced one half, full vigour was retained for seven days. If the abstention be prolonged, however, there is eventually great loss of muscular strength, often mental debility, some feverish and dyspeptic symptoms. Then follow anæmia and great prostration. The elimination of nitrogen in the form of urea greatly lessens, though it never ceases, while the uric acid diminishes in a less degree. If starch be largely supplied, the weight of the body does not lessen for seven or eight days (Hammond).

If the deprivation of albuminoids be less complete (70 to 100 grains of nitrogen being given daily), the body gradually lessens in activity, and passes into more or less of an adynamic condition, which predisposes to the attacks of all the specific diseases (especially of malarious affections and typhus) and of pneumonia, and modifies the course of some of these diseases, as, for instance, of enteric fever, which runs its course, with less elevation of temperature than usual, and with less or with no excess of ureal excretion.

The deprivation of starches can be borne for a long time if fat be given, but if both fat and starch be excluded, though albuminoids be supplied, illness is produced in a few days. Nor is it difficult to explain this: as albuminoids contain 53·3 per cent. of total carbon (of which about 49 per cent. is available for nutrition) and 16 per cent. of nitrogen, to supply 4800 grains of carbon, no less than 1585 grains of nitrogen must be introduced, a quantity five times as great as the system can easily assimilate, unless enormous exertion be taken, and then the quantity of carbon becomes insufficient.

Men can be fed on meat for a long time, as a good deal of fat is then introduced, and if the meat be fresh (and raw?), scurvy is not readily induced.

The deprivation of fat does not appear to be well borne, even if starches be given; but the exact effects are not known. The great remedial effects produced by giving fat in many of the diseases of obscure malnutrition prove that the partial deprivation of fat is both more common and more serious than is supposed. In all the diets ordered for soldiers, prisoners, &c., the fat is greatly deficient in every country. The deprivation of the salts

is also evidently attended with marked results, which are worthy of more attention than they have yet received.

Bad effects are also produced if the intervals between meals are too long; this is a matter in which there is great individual difference, and need not be further referred to.

Sub-Section II.—Conditions of Digestibility and Assimilation.

A great number of diseases are produced, not by alterations in quantity or by imperfections in the quality of the raw food, but by conditions of indigestibility, either dependent on physical or chemical conditions of the food itself or of the digestive fluids. To some persons certain foods are indigestible at all times, or at particular times. Indigestibility leads to retention, and then to the results of retention, viz., chemical changes and putrefaction going on in the stomach and bowels under the influence of warmth, moisture, and air. Then irritation is produced, and dyspepsia, diarrhœa, or dysentery is caused.

Indigestibility extends, however, farther than this. There is some reason for thinking that the albuminoids sometimes pass into the circulation less properly prepared than usual to undergo the action of the liver, and that they therefore produce irritation of that organ, and, passing into the blood in some unassimilable state, produce irritation of the skin or kidneys. Sometimes, indeed, albumen appears in the urine, as if it had circulated like a foreign body in the blood. Such conditions are usually allied to some evident error in primary digestion, but occasionally are not obviously accompanied by any gastric disorder. Whether there is any similar imperfection in the digestion of starch or fat is not at present known.

Sub-Section III.—Conditions of Quality.

Altered quality of what is otherwise good food produces a great number of diseases. Most of these are referred to under the headings of the different articles of food, and the subject is merely introduced here to complete the general sketch of the production of disease from food.

In inquiring, then, into the effect of food, the following appears to be the best order of procedure:—

1. Is the food excessive or deficient in quantity as a whole or in any of the primary classes of aliments?
2. Are the different articles digestible and assimilable, or, from some cause inherent in the food or proper to the individual, is there difficulty in primary digestion or want of proper assimilation?
3. Is the quality of the food altered either before or after cooking?

CHAPTER IX.

QUALITY, CHOICE, AND COOKING OF FOOD, AND DISEASES ATTRIBUTABLE TO IMPROPER QUALITY.

SECTION I.

MEAT.

The advantages of meat as a diet are—its large amount of nitrogenous substances, the union of this with much fat, the presence of important salts (viz., chloride, phosphate, and carbonate of potassium, or a salt forming carbonate on incineration), and iron. It is also easily cooked, and is very digestible; it is probably more easily assimilated than any vegetable, and there is a much more rapid metamorphosis of tissue in carnivorous animals than in vegetable feeders. Whether the use of large quantities of meat increases the bodily strength or the mental faculties more than other kinds of nitrogenous food is uncertain. The great disadvantage of meat is the want of starch.

The composition of fresh and salt meat has been already given; but the figures in such tables give a very imperfect idea of the value of a ration. For the most part they refer to the meat proper, without taking into consideration the amount of gristle, &c., which makes up part of the ration. Thus in rations analysed at Netley the following results were obtained:—

	Rump of Beef.		*Shank of Mutton.*	
	Flesh alone.	Whole Ration, exclusive of Bone.	Flesh alone.	Whole Ration, exclusive of Bone.
Water, . . .	74·0	60·5	71·9	52·7
Albuminoids, . .	22·0	21·5	18·8	13·0
Fat, ...	2·2	9·1	8·4	25·3
Ash, ...	1·6	1·3	1·0	0·9
Total, . .	99·8	92·4	100·1	91·9

In each case it will be observed that the analysis of the flesh alone does not deviate very widely from the tabulated statements, whereas the whole ration does so materially. In particular, there is about 8 per cent. of total weight unaccounted for, due to tough gristle and fibrous tissue not amenable to the ordinary method of analysis. The detailed constituents of the albuminoids are also important, as the following results will show:—

	Rump of Beef. Flesh alone.	*Rump of Beef.* Whole Ration, exclusive of Bone.	*Shank of Mutton.* Flesh alone.	*Shank of Mutton.* Whole Ration, exclusive of Bone.
Digestible albuminoids, .	13·5	14·2	7·6	4·0
Peptones, . . .	2·5	2·2	2·0	1·5
Meat extracts, . .	1·2	0·9	5·5	2·9
Total useful, . . .	17·2	17·3	15·1	8·4
Indigestible albuminoids, .	4·8	4·2	3·7	4·6
Total albuminoids per cent. as above, . .	22·0	21·5	18·8	13·0

From this we see that there is great diversity in the value of different rations; the numbers given here may be taken to represent the extremes, so that the mean value may be assumed at about 17 per cent. total albuminoids, and about 13 per cent. of useful (*i.e.* assimilable) albuminoids.

Bone constitutes *one-fifth* of the soldier's ration on the average; in the two rations above examined bone formed 17 per cent. in both cases. Bones contain a large amount of nutrient matter, a considerable part of which is extracted by boiling, and more could be obtained if the bones were crushed or ground. The following was the composition of the bones in the beef ration:—

Moisture, ...	12·1
Albuminoids, . . .	24·5
Fat, ...	11·0
Ash, ...	48·6
Loss, ...	3·8
Total, .	100·0

Constituents of albuminoids—	
Digestible albuminoids, .	10·3
Peptones, ...	1·9
Extractives, . . .	1·0
Total useful, .	13·2
Indigestible albuminoids, .	11·3
Total, .	24·5

Bones make the most palatable soup, and, as above shown, may be made to yield an important addition to the useful albuminoids.

Another measure of the value of meat is the amount of extract which can be obtained from it by means of hot and cold water. Pure flesh should yield about 6 per cent., of which about 5 per cent. should be organic; but the average of a ration would, of course, be less. Thus in the beef ration already mentioned the total extract of the flesh was 6·1 and the organic 4·95; whilst the whole ration (bone excluded) gave a total of 3·6, of which 2·8 was organic.

The salts or ash of meat consist of chlorides and phosphates chiefly, more than a third of the ash consisting of phosphoric acid. Stölzel[1] found 8·9 per cent. of carbonic acid in the ash, which probably indicates lactic acid, and it is suggested that this may perhaps give fresh raw meat some anti-scorbutic properties which may be altered by cooking. The ash is alkaline.

Beef, mutton, and pork form the chief meats eaten by the soldier.

In time of peace he only receives as fresh meat beef and mutton, and more seldom pork; in time of war he has salt beef and salt pork.

The corned beef (from Chicago, Australia, and New Zealand) is very good meat, palatable, and more nutritious than the more strongly salted

[1] Liebig's *Annalen*, Band lxxvii. p. 256.

beef. Only 10 per cent. of its total albuminoids (which ranged from 18 to 31 per cent.) was found to be indigestible in experiments at Netley. The amount of extract is a little less than in fresh meat, as some is necessarily lost in the salting and compressing, but it was found to be 6 per cent., of which 4 was animal. The nutritious value of the fully salted rations is more uncertain.

The meat is supplied by contractors, or is, at some stations, furnished by the Commissariat, who have their own slaughter-houses.

The medical officer may be called on to see the animals during life, or to examine the meat.

Sub-Section I.—Inspection of Animals.

Animals should be inspected twenty-four hours before being killed.[1]—In this country killing is done twenty-four or forty-eight hours before the meat is issued; in the tropics only ten or twelve hours previously.

Animals should be well grown, well nourished, and neither too young nor too old. The flesh of young animals is less rich in salts, fat, and syntonin, and also loses much weight (40 to 70 per cent.) in cooking.

Weight.—An ox should weigh not less than 600 ℔, and will range from this to 1200 ℔. The French rules fix the minimum at 250 kilogrammes (= 550 ℔ av.). The mean weight in France is 350 kilogrammes (= 770 ℔ av.). A cow may weigh a few pounds less; a good fat cow will weigh from 700 to 740 ℔. A heifer should weigh 350 to 400 ℔. The French rules fix the minimum of the cow's weight at 160 kilogrammes (= 352 ℔). The mean weight of cows in France is 230 kilogrammes (= 506 ℔).

There are several methods of determining the weight; the one most commonly used in this country is to measure the length of the trunk from just in front of the scapulæ to the root of the tail, and the girth or circumference just behind the scapulæ; then multiply the square of girth by 0·08, and the product by the length, the dimensions in cubic feet are obtained; each cubic foot is supposed to weigh 42 ℔ avoirdupois. The formula is $(C^2 \times \cdot 08) \times L \times 42$; or $\frac{2}{3}(C^2 \times 5L)$; the result in either case gives the weight in ℔ avoirdupois. An ox or cow gives about 60 per cent. of meat, exclusive of the head, feet, liver, lungs, and spleen, &c.[2] The skin is $\frac{1}{18}$ of the weight; the tallow $\frac{1}{12}$. In very fat cattle the weight may be 5 per cent. more, and in very lean cattle 5 per cent. less than the actual weights found by this rule.

A full-grown sheep will weigh from 60 to 90 ℔, but the difference in different breeds is very great. It also yields about 60 per cent. of available food.

A full-grown pig weighs from 100 to 180 ℔ or more, and yields about 75 to 80 per cent. of available food.

Age.—The age of the ox and cow should be from three to eight years:[3] the age is told chiefly by the teeth, and less perfectly by the horns. The temporary teeth are in part through at birth, and all the incisors are through in twenty days; the first, second, and third pairs of temporary molars are through in thirty days; the teeth are grown large enough to

[1] Every contract should have a clause giving officers the power of inspection.

[2] The animal is divided into carcass and offal; the former includes the whole of the skeleton (except the head and feet), with the muscles, membranes, vessels, and fat, and the kidneys and fat surrounding them. The offal includes the head, feet, skin, and all internal organs, except the kidneys.

[3] Dr Pavy gives four years for the highest perfection of ox beef, on the authority of an "intelligent and experienced grazier."

touch each other by the sixth month; they gradually wear and fall in eighteen months; the fourth permanent molars are through at the fourth month; the fifth at the fifteenth; the sixth at two years. The temporary teeth begin to fall at twenty-one months, and are entirely replaced by the thirty-ninth to the forty-fifth month; the order being—central pair of incisors gone at twenty-one months; second pair of incisors at twenty-seven months; first and second temporary molars at thirty months; third temporary molars at thirty months to three years; third and fourth temporary incisors at thirty-three months to three years. The development is quite complete at from five to six years. At that time the border of the incisors has been worn away a little below the level of the grinders. At six years the first grinders are beginning to wear, and are on a level with the incisors. At eight years the wear of the first grinders is very apparent. At ten or eleven years the used surfaces of the teeth begin to bear a square mark surrounded with a white line; and this is pronounced on all the teeth by the twelfth year; between the twelfth and fourteenth year this mark takes a round form.

The rings on the horns are less useful as guides. At ten or twelve months the first ring appears; at twenty months to two years, the second; at thirty to thirty-six months, the third ring; at forty to forty-six months, the fourth ring; at fifty-four to sixty months, the fifth ring, and so on. But at the fifth year the first three rings are indistinguishable, and at the eighth year all the rings. Besides, the dealers file the horns.

In the sheep, the temporary teeth begin to appear in the first week, and fill the mouth at three months; they are gradually worn and fall about fifteen or eighteen months. The fourth permanent grinders appear at three months, and the fifth pair at twenty to twenty-seven months. A common rule is "two broad teeth every year." The wear of the teeth begins to be marked at about six years.

The age of the pig is known up to three years by the teeth; after that there is no certainty. The temporary teeth are complete in three or four months; about the sixth month the premolars, between the tusks and the first pair of molars, appear; in six or ten months the tusks and posterior incisors are replaced; in twelve months to twc years the other incisors; the four permanent molars appear at six months; the fifth pair at ten months; and the sixth and last molars at eighteen months.

Condition and Health.—There ought to be a proper amount of fat, which is best felt on the false ribs and the tuberosities of the ischia, and the line of the belly from the sternum to the pelvis; the flesh should be tolerably firm and elastic; the skin should be supple.

As showing health, we should look to the general ease of movements, the quick bright eye; the nasal mucous membrane red, moist, and healthy-looking; the tongue not hanging; the respiration regular, easy; the expired air without odour; the circulation tranquil; the excreta natural in appearance.

When sick, the coat is rough or standing; the nostrils dry or covered with foam; the eyes heavy; tho tongue protruded; the respiration difficult; movements slow and difficult; there may be diarrhœa; or scanty or bloody urine, &c. In the cow the teats are hot.

The diseases of cattle which the medical officer should watch for are—

1. *Epidemic Pleuro-pneumonia* (or lung disease).—Not easily recognised at first, but with marked lung symptoms after a few days.
2. *Foot and Mouth Disease* (murrain, aphtha, or eczema epizootica).—At once recognised by the examination of the mouth, feet, and teats.

3. *Cattle Plague* (typhus contagiosus, Steppe disease, Rinderpest).—Recognised by the early prostration (hanging of head, drooping of ears), shivering, running from eyes, nose, and mouth, peculiar condition of tongue and lips, cessation of rumination, and then by abdominal pain, scouring, &c.
4. *Anthrax* (malignant pustule, carbuncular fever).—If boils and carbuncles form, they are at once recognised; if there is erysipelas, it is called black quarter, quarter ill, or blackleg (erysipelas carbunculosum), and is easily seen. The peculiar organism, *Bacillus anthracis*, may be detected.
5. *Simple inflammatory affections* of the lungs, bronchitis, and simple pneumonia. All have obvious symptoms.
6. *Dropsical affections* from kidney or heart disease.
7. *Indigestion*, often combined with apoplectic symptoms.

A great number of other diseases attack cattle, which it is not necessary to enumerate. All the above are tolerably easily recognised. The presence of *Tænia mediocanellata* cannot, it would seem, be detected before death.

The diseases of sheep are similar to those of cattle; they suffer also in certain cases from splenic apoplexy or "braxy," which is considered by Professor Gamgee to be a kind of anthrax, and is said to kill 50 per cent. of all young sheep that die in Scotland; the animals have a "peculiar look, staggering gait, bloodshot eyes, rapid breathing, full and frequent pulse, scanty secretions, and great heat of the body."[1]

The smallpox in sheep (*Variola ovina, clavelée* of the French) is easily known by the flea-bitten appearance of the skin in the early stage, and by the rapid appearance of nodules or papulæ and vesicles.

The sheep is also subject to black quarter (*Erysipelas carbunculosum*); one limb is affected, and the limp of the animal, the fever, and the rapid swelling of the limb are sufficient diagnostic marks.

The sheep, of course, may suffer from acute lung affection, scouring, red water (hæmaturia), and many other diseases. Of the chronic lung affections, one of the most important is the so-called "phthisis," which is produced by the ova of *Strongylus filaria.* This entozoon has not yet been found in the muscles, and the meat is said to be good. The rot in sheep (fluke disease) is caused by the presence of *Distoma hepaticum* in large numbers in the liver, and sometimes by other parasites. The principal symptoms are dulness, sluggishness, followed by rapid wasting and pallor of the mucous membrane, diarrhœa, yellowness of the eyes, falling of the hair, and dropsical swellings. The animal is supposed to take in *Cercaria* (the embryotic stage of *distoma*) from the herbage. The so-called "gid," "sturdy," or "turnsick," is caused by the development of *Cœnurus cerebralis* in the brain.

The pig is also attacked by anthrax in different forms, by enteric fever, and by hog cholera.[2] The swelling in the first case, and the scouring, fever, and prostration in the second, are sufficient diagnostic marks. In 1864 a

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[1] *Fifth Report of the Medical Officer to the Privy Council*, p. 222.

[2] The late Dr Cobbold (*Monthly Microscopical Journal*, Nov. 1871) pointed out that the pig is affected, both in America and Australia, with a large parasite (*Stephanurus dentatus*). This worm is found chiefly though not solely in the fat, and is at first free and then encysted; the cyst is large, and may be $1\frac{3}{4}$ inch in length and $\frac{1}{2}$ inch in diameter. The full grown worm may be as much as $1\frac{1}{2}$ inch in length. Three to six eggs are found in the cyst, and the young worms migrate. During their migration, it has been surmised that they cause the "hog cholera."

severe fever of this kind, with or without scouring, prevailed among the pigs in London.

The so-called measle of the pig is caused by the presence in the muscle of *Cysticercus cellulosæ.* It is detected in the following way :—The "measle trier" throws the pig on its back, draws out and wipes the tongue, and looks and feels for the sublingual vesicles containing the *Cysticerci.* Sometimes a bit is cut out of the muscle under the tongue, and the *Cysticerci* are microscopically examined. A small harpoon can be used for this purpose, and gives little pain. Sometimes the *Cysticercus* can be seen on the conjunctiva, or on the folds of the anus. When the disease is far advanced the animal is dull, the eyes heavy, appetite bad. These symptoms are, however, not peculiar; there is said to be sometimes tenderness in the groin (Grève), but, according to Delpech, this is very uncertain; a better sign is a certain amount of swelling of the shoulder, which causes a sort of constriction of the neck, and somewhat impedes the movements of the animals (Delpech). The presence of *Trichina spiralis* is indetectable before death, unless found in the muscles under the tongue.

Sub-Section II.—Inspection of Dead Meat.[1]

1. *Fresh Meat.*

Meat should be inspected, in temperate climates, twenty-four hours after being killed; in the tropics, earlier.

The following points must be attended to :—

(*a*) *Quantity of Bone.*—In lean animals the bone is relatively in too great proportion; taking the whole meat, 20 per cent. should be allowed.

(*b*) *Quantity and Character of the Fat.*—It should be sufficient, yet not excessive, else the relative proportion of albuminous food is too low; it should be firm, healthy-looking, not like jelly, or too yellow; without hæmorrhage at any point. The kind of feeding has an effect on the colour of the fat; some oil-cakes give a marked yellow colour.

The late Professor Gamgee stated that pigs fed on flesh have a peculiarly soft diffluent fat, and emit a strong odour from their bodies. According to the same authority, the butchers rub melted fat over the carcass of thin and diseased animals to give the glossy look of health.

(*c*) *Condition of the Flesh.*—The muscles should be firm, and yet elastic; not tough; the pale moist muscle marks the young animal, the dark-coloured the old one; the muscular fasciculi are larger and coarser in bulls than oxen. A deep purple tint is said to indicate that the animal has not been slaughtered, but has died with the blood in it (Letheby). When good meat is placed on a white plate, a little reddish juice frequently flows out after some hours. Good meat has a marbled appearance from the ramifica-

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[1] In the city of London, about 1 ton in 750 tons is condemned, but much escapes detection. Letheby (*Lectures on Food*, 2nd edition, p. 209) stated that 700 tons of meat were destroyed in seven years; of this, 850,653 lb were diseased, 568,375 lb were putrid, and 193,782 lb were from animals which had died of accident or disease. "In the city of London the practice is to condemn the flesh of animals infected with certain parasites, such as measles and flukes, &c., and of animals suffering from fever or acute inflammatory affections, or rinderpest, pleuro-pneumonia, and the fever of parturition, and of animals emaciated by lingering disease, and those which have died from accident or from natural causes, as well as all meat tainted with physic, or in a high state of putrefaction" (*Ibid.*, p. 210). It may be a question if meat should be condemned in some of these cases, as, for instance, pleuro-pneumonia. In India, meat with *Cysticerci* is now ordered to be received, but to be carefully cooked; but it would be very difficult to ensure that proper cooking shall be always had recourse to.

tions of little veins of fat among the muscles (Letheby). There should be no lividity on cutting across some of the muscles; the interior of the muscle should be of the same character, or a little paler; there should be no softening, mucilaginous-like fluid, or pus, in the intermuscular cellular tissue. This is an important point, which should be closely looked to. The intermuscular tissue becomes soft, and tears easily when stretched in commencing putrefaction.

The degree of freshness of meat in commencing putrefaction is judged of by the colour, which becomes paler; by the odour, which becomes at an early stage different from the not unpleasant odour of fresh meat, and by the consistence. Afterwards the signs are marked, the odour is disagreeable, and the colour begins to turn greenish. In diseased meat there is a disagreeable odour, sometimes a smell of physic; very discoverable when the meat is chopped up and drenched with warm water. It is a good plan to push a clean knife into the flesh up to its hilt. In good meat the resistance is uniform; in putrefying meat some parts are softer than others. The smell of the knife is also a good test. *Cysticerci* and *Trichinæ* should be looked for.

(*d*) *Condition of the Marrow.*—In temperate climates the marrow of the hind legs is solid twenty-four hours after killing; it is of a light rosy red. If it is soft, brownish, or with black points, the animal has been sick, or putrefaction is commencing. The marrow of the fore legs is more diffluent; something like honey—of a light rosy red.

(*e*) *Condition of Lungs and Liver.*—Both should be looked at to detect *Strongylus filaria* in the lungs, *Distoma* in the liver; also for the presence of multiple abscesses.

(*f*) To detect *cattle plague*, the mouth, stomach, or intestines must be seen; no alterations have as yet been pointed out in the naked-eye appearance of the muscles, though under the microscope they are found to be degenerating like the muscles in human enteric fever (Buchanan).

But meat cannot be fully judged of till it has been cooked, so as to see how much it loses in roasting or boiling; whether the fibres cook hard, &c.

In countries where there are goats, the attached foot of the sheep should be sent in for identification.

Decomposing sausages are difficult of detection until the smell alters. Artmann recommends mixing the sausage with a good deal of water, boiling and adding freshly-prepared lime water. Good sausages give only a faint not unpleasant, ammoniacal smell; bad sausages give a very offensive, peculiar ammoniacal odour.

Microscopic Examination of Meat.

In the flesh of cattle, or of the pig, *Cysticerci* may be found. They are generally visible to the naked eye as small round bodies; when placed under a microscope with low power, their real nature is seen; they are sometimes so numerous as to cause the flesh to crackle on section. The smallest *Cysticercus* noticed by Leuckart in the pig was about $\frac{4}{100}$ths of an inch long and $\frac{3}{100}$ths broad; but they are generally much larger, and will reach to $\frac{2}{10}$ths or $\frac{3}{10}$ths or $\frac{3}{4}$ths of an inch. In some countries they are extremely common in cattle, and have been a source of considerable trouble in North-West India. *Cysticercus* of the ox produces in man *Tænia mediocanellata*. In sheep Cobbold described a small *Cysticercus* with a double crown of hooks, 26 in number. He thought that possibly a special *Tænia* might arise from

this.[1] In diagnosing *Cysticerci* of pork the hooklets should always be seen.

Trichinæ may be present in the flesh of the pig; if encapsuled they will be seen with the naked eye as small round specks; but very often a microscope is necessary. A power of 50 to 100 diameters is sufficient. The best plan is to take a thin slice of flesh; put it into liquor potassæ (1 part to 8 of water), and let it stand for a few minutes till the muscle becomes clear; it must not be left too long, otherwise the *Trichinæ* will be destroyed. The white specks come out clearly, and the worm will be seen coiled up. If the capsule is too dense to allow the worm to be seen, a drop or two of weak hydrochloric acid should be added. If the meat is very fat, a little ether or benzine may be put on it in the first place. The parts most likely to be infected are said to be the muscular part of the diaphragm, the intercostal muscles, and the muscles of the eye and jaw.[2] In diagnosing *Trichinæ*, the coiled worm should be distinctly seen. *Stephanurus dentatus* in the pig has been already referred to.

The so-called *Psorospermia*, or Rainey's capsules, must not be mistaken for *Trichinæ*, nor indeed with care is error possible. These are little, almost transparent, bodies, found in the flesh of oxen, sheep, and pigs. They are in shape oval, spindle-shaped, or sometimes one end is pointed and the other rounded, or they are kidney-shaped. The investing membrane exhibits delicate markings, caused by a linear arrangement of minute, hair-like fibres, which Mr Rainey [3] stated increase in size as the animal gets older. They sometimes are pointed, and the appearance under a high power (1000 diameters) is as if the investment consisted of very delicate, transparent, conical hairs, terminating in a pointed process.[4] The contents of the cysts consist of granular matter, the granules or particles of which, when mature, are oval, and adhere together, so as to form indistinct divisions of the entire mass. The length varies from $\frac{1}{300}$th to $\frac{1}{4}$th of an inch. They are usually narrow; they lie within the sarcolemma, and appear often not to irritate the muscle.

Up to the present time no injurious effect has been known to be produced on men by these bodies, notwithstanding their enormous quantities in the flesh of domestic animals, nor have they been discovered in the muscles of men. But in pigs these bodies sometimes produce decided illness; besides general signs of illness, there are two invariable symptoms, viz., paralysis of the hind legs, and a spotty or nodular eruption.[5] In sheep, they have been known to affect the muscle of the gullet, and produce abscesses, or what may be called so, viz., swellings sometimes as large as a nut, and containing a milky, purulent-looking fluid, with myriads of these capsules in it. Sheep affected in this way often die suddenly.[6]

It is by no means improbable that some effect on man may be hereafter discovered to be produced.

Some bodies, which have been also termed *Psorospermia*, found in the liver of the rabbit, and other parts, and in the liver of man, and which have been described by many observers in different terms,[7] may possibly be found

[1] Surgeon-Major Oldham describes *Cystiecercus tenuicollis* (from *Tænia marginata* of dog) as common in the sheep of the Punjab; it has four suckers and a double coronet of 32 hooks.—*Indian Medical Gazette*, August 1873.

[2] Lion, *Comp. des Sanit.-Pol.*, p. 171.

[3] *Phil. Trans.*, 1857.

[4] Beale, in *Third Report of the Cattle Plague Commission*, Appendix.

[5] Virchow's *Archiv*, Band xxxviii. p. 355.

[6] Leisering, in Virchow's *Archiv*, Band xxxvii. p. 431.

[7] Leuckart, *Die Menschl. Paras.*, Band i. p. 740; Stieda, Virchow's *Archiv*, Band xxxii. 132; Roloff, Virchow's *Archiv*, Band xliii. p. 512.

in other animals, as they have been seen in the dog by Virchow. They are quite different from Rainey's corpuscles; they are oval or rounded bodies, at first with granular contents, and then with aggregations of granules into three or four rounded bodies, on which something like a nucleolus is seen. They have often been mistaken for pus cells.

Some other bodies occur in the flesh of pigs, the nature of which is not yet known. Wiederhold[1] described a case in which little white specks, with all the appearance at first of encapsuled *Trichinæ*, could not be proved to be so, and their real nature was quite obscure.

Virchow has described little concretions in the flesh of the pig, which seemed to be composed of guanin;[2] these were also at first taken for encapsuled *Trichinæ*.

Roloff[3] has noted little hard round nodules in the flesh of the pig; some seem very small, others as large as the head of a pin, with little prolongations running to the surrounding muscular fibres to which they are attached. On the outside of these bodies are bundles of fine hairs or needles, sometimes arranged in quite a feather-like form. The bodies have a great resemblance to the guanin bodies of Virchow, but the needles are not crystalline. Roloff asked if these bodies were of post-mortem origin.

It is hardly necessary to state that in cutting across meat small bits of tendons or fascia, sometimes very like a little cyst, will be found; but common care will prevent a mistake.

2. *Salt Meat.*

It is not at all easy to judge of salt meat, and the test of cooking must often be employed. The following points should be attended to:—

(*a*) *The salting has been well done, but the parts inferior.*—This is at once detected by taking out a good number of pieces; those at the bottom of the cask should be looked at, as well as those at the top.

(*b*) *The salting well done, and the parts good, but the meat old.*—Here the extreme hardness and toughness, and shrivelling of the meat, must guide us. It would be desirable to have the year of salting placed on the cask of salt beef or pork.

(*c*) *The salting well done, but the meat bad.*—If the meat has partially putrefied, no salting will entirely remove its softness; and even there may be putrefactive odour, or greenish colour. A slight amount of decomposition is arrested by the salt, and is probably indetectable. *Cysticerci* are not killed by salting, and can be detected. Measly pigs are said to salt badly, but according to Gamgee this is not the case.

(*d*) *The salting badly done, either from haste or bad brine.*— In both cases signs of putrefaction can be detected; the meat is paler than it should be; often slightly greenish in colour, and with a peculiar odour.

It should be remembered that brine is sometimes poisonous; this occurs in cases where the brine has been used several times; a large quantity of animal substance passes into it, and appears to decompose. The special poisonous agent has not been isolated, but is probably a ptomaine.

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[1] Virchow's *Archiv*, Band xxxiii. p. 549.
[2] *Ibid.*, Band xxxv. p. 358.
[3] *Ibid.*, Band xliii. p. 524.

SUB-SECTION III.—DISEASES ARISING FROM ALTERED QUALITY OF MEAT.

A very considerable quantity of meat from diseased animals is brought into the market, but the amount is uncertain.

Instances are not at all uncommon in which persons, after partaking of butcher's meat, have been attacked with serious gastro-intestinal symptoms (vomiting, diarrhœa, and even cramp), followed in some cases by severe febrile symptoms. The whole complex of symptoms somewhat resembles cholera at first, and afterwards enteric fever. The meat has often been analysed for the purpose of detecting poison, but none has been found.[1] In the records of these cases, the kind of meat, the part used, and the origin from a diseased animal are not stated, and, in some cases, it may be conjectured that the cooking, and not the meat, was in fault. Still, the instances are becoming numerous, and are increasing every day, as attention is directed to the subject. We should conclude from general principles, that as all diseases must affect the composition of flesh, and as the composition of our own bodies is inextricably blended with the composition of the substances we eat, it must be of the greatest importance for health to have these substances as pure as possible. Animal poisons may indeed be neutralised or destroyed by the processes of cooking and digestion, but the composition of muscle must exert an influence on the composition of our own nitrogenous tissues which no preparation or digestion can remove.

On looking through the literature of the subject, however, we find less evidence than might be expected. This is probably partly owing to imperfect observation, especially when we think for how long a time *Trichina* disease was overlooked.

1. *The flesh of healthy animals may produce Poisonous Symptoms.*—This is the case with certain kinds of fish, especially in the tropical seas. There is no evidence that the animal is diseased, and the flesh is not decomposed; it produces, however, violent symptoms of two kinds—gastro-intestinal irritation, and severe ataxic nervous symptoms, with great depression and algidity. The little herring (*Clupea harengo minor*), the silver-fish (*Zeus gallus*), the pilchard, the white flat-fish, and several others, have been known to have these effects.[2] In some cases, though not in all, the poison is developed during the breeding time. Oysters (even when in season) and mussels have been known to produce similar symptoms, without any decomposition. The production of dyspepsia and nettle rash in some persons from eating shell-fish need scarcely be mentioned.

Among the *Mammalia* the flesh of the pig sometimes causes diarrhœa—a fact noticed by Dr Parkes in India, and often mentioned by others. The flesh is probably affected by the unwholesome garbage on which the pig feeds. Sometimes pork, not obviously diseased, has produced choleraic symptoms.[3] In none of these cases has the poison been isolated.

2. *The flesh of healthy animals, when decomposing,* is eaten sometimes without danger; but it occasionally gives rise to gastro-intestinal disorder—vomiting, diarrhœa, and great depression; in some cases severe febrile symptoms occur, which are like typhus, on account of the great cerebral complication. Cooking does not appear entirely to check the decomposition.

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[1] See Professor Gamgee's paper in the *Fifth Report of the Medical Officer to the Privy Council*, 1863, p. 287. Reference is made to cases noted by Maclagan, Taylor, Letheby, Dundas, Thomson, and Keith.

[2] A list of more than forty fishes, which are occasionally poisonous, is given by Pappenheim.—*Hand. der Sanitäts-Pol.*, Band i. p. 395.

[3] Kesteven cites a good case in which twelve persons were affected.—*Med. Times and Gazette*, March 5, 1864.

It appears to be, in some cases, the acid fluids of cooked meat which promote this alteration.

Sausages and pork-pies, and even beefsteak-pies,[1] sometimes become poisonous from the formation of an as yet unknown substance, which is perhaps of a fatty nature or a ptomaine. It is not trimethylamine, amylamine, or phenylamine—these are not poisonous (Schlossberger). The symptoms are severe intestinal irritation, followed rapidly by nervous oppression and collapse.[2] Neither salts nor spices hinder the production of this poison. M. van den Corput attributes the poisonous effects of sausages to a *fungus*, of the nature of *Sarcina*, or what he terms *Sarcina botulina*.[3]

Dr Ballard has reported two remarkable cases of poisoning by ham and hot baked pork. The first occurred at Welbeck in 1880, and the second at Nottingham in 1881. In both instances a number of persons who partook of the meat were taken ill, and some died. Dr Klein examined the meat, and found it loaded with *Bacilli*, which were also found in the organs of the fatal cases. Guinea-pigs and mice, inoculated with the fluids of the body, died with pneumonia and peritonitic symptoms: *Bacilli* were found in the organs.[4]

Oysters and shell-fish, when decomposing, produce also marked symptoms of the same kind. Rotten fish are used, however, by the Burmese, Siamese, and Chinese as a sort of condiment, without bad effects.

3. *The fresh and not decomposing flesh of diseased animals* causes in many cases injurious effects. A good deal of difference of opinion, however, exists on this point, and it would seem that a more careful inquiry is necessary. The probability is that, when attention is directed to the subject, the effect of diseased meat will be found to be more considerable than at present believed.[5] At the same time, we must not go beyond the facts as they are at present known to us, and at present certainly bad effects have been traced in only a few instances; perhaps the heat of cooking is the safeguard.

(*a*) *Accidents.*—The flesh of animals killed on account of accidents may be eaten without injury.

(*b*) The flesh of *over-driven* animals, according to the late Professor Gamgee, contains a poison which often produces eczema on the skin of those who handle it; and eating the flesh is said to "have been attended with bad effects."

(*c*) *Early Stage of Acute Inflammatory Disease.*—The meat is not apparently altered, and it is said that some of the primest meat in the London market is taken from beasts in this condition; it is not known to be injurious, but it has been recommended that the blood should be allowed entirely to flow out of the body, and should not be used in any way.

(*d*) *Chronic Wasting Diseases—Phthisis, Dropsy, &c.*—The flesh is pale, cooks badly, and gives rise to sickness and diarrhœa. It also soon begins

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[1] Dr de Chaumont has seen very severe symptoms produced, diarrhœa and partial collapse, from eating beefsteak-pie which presented nothing unpleasant to the taste.

[2] A severe case of poisoning by liver sausages took place at Middelburg, in Holland, in March 1874. Nearly 400 were attacked, and out of 343 reported cases 6 died. The symptoms commenced a few hours after the sausages were eaten, and consisted of nausea and vomiting, diarrhœa with offensive stools, and abdominal pain and high fever. The symptoms, after apparent convalescence, recurred for several days, and at last became quite of an intermittent character. Chemical and microscopical examination failed to detect anything, except that there were quantities of the minutest organisms in the sausages (*Centralblatt für die Med. Wiss.*, 1875, No. 14, p. 219).

[3] Quoted by Letheby, *Chemical News*, Feb. 1869.

[4] *Report of the Medical Officer of the Local Government Board.*

[5] Professor Gamgee said that one-fifth of the meat in London was more or less diseased.

to decompose, and then causes very severe gastro-intestinal derangement. Grave doubts have recently arisen as to whether tuberculosis may not be communicable to man through the flesh of cattle suffering from that disease.[1]

(*e*) *Chronic Nervous Fevers.*—Same as above.

(*f*) *Epidemic Pleuro-pneumonia of Cattle.*—Much doubt exists as to the effect of this disease on the meat. It is hardly possible that the flesh should not be seriously altered in composition, but it seems certain that a large quantity is daily consumed without apparent injury. It is said, on the authority of Drs Nicolson and Frank, who made very careful inquiries on this point, that the Kaffirs ate their cattle, when destroyed by the epidemic lung disease which prevailed at the Cape a number of years ago, without injury. Dr Livingstone, however, states that the use of the flesh produces carbuncle.

(*g*) *Anthrax and Malignant Pustule.*—Many of the older authors (Ramazzini, Lancisi, quoted by Lévy) mention facts tending to prove the danger of using the flesh of animals affected with malignant pustule. Chaussier also affirmed the same thing, but subsequently modified his opinion considerably. The apparent increase in the number of cases of malignant pustule in men has been ascribed to eating the flesh of animals with this disease, but it is quite as likely that inoculation may have taken place in other ways.

The evidence laid before the Belgian Academy of Medicine led them to believe the flesh of cattle affected with carbuncular fevers to be injurious, and it is not allowed to be sold.

It has been supposed that the outbreaks of boils, which have certainly become more prevalent of late years, are produced by meat of this kind, but the evidence is very imperfect.

Menschel [2] has recorded a case in which twenty-four persons were seized with malignant pustule, the majority after eating the flesh of beasts suffering from the disease, the others from direct inoculation. Those who ate the flesh were attacked in three to ten days; those who were inoculated in three to six days. It is also stated that pigs fed on the flesh got the disease, and that a woman who ate some of the diseased pork was also attacked.

On the other hand, several old authors, and more lately Neffel,[3] assert that the Kirghises constantly eat horses and cattle (either killed or dying spontaneously) affected with malignant pustule, without injury.

Parent-Duchâtelet [4] quotes a case from Hamel (1737), in which a bull infected three persons who aided in killing it and a surgeon who opened one of the tumours of a person affected; yet, of more than 100 persons who ate the flesh roasted and boiled, no one experienced the slightest inconvenience, and Parent states that many other cases are known in literature.

Parent-Duchâtelet and Lévy [5] quote from Morand (1776) an instance in which two bulls communicated malignant pustule to two butchers by inoculation, yet the flesh of the animals was eaten at the "Invalides" without injury. But both these instances are of old date. Pappenheim [6] states (without giving special instances) that there are many cases in which no bad effect resulted from the cooked flesh of *charbon*—that the peasants of

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[1] Creighton, on *Bovine Tuberculosis in Man*; also *Transactions of the International Medical Congress*, 1881, vol. iv. p. 481.

[2] *Preuss. Med. Zeit.*, 4th June 1862; and Canstatt's *Jahresb.*, 1862, Band iv. p. 257.

[3] Canstatt's *Jahresb.* for 1860, Band ii. p. 137.

[4] Tom. ii. p. 196.

[5] *Traité d' Hygiène*, 1879, tom. ii. p. 630.

[6] *Handb. der Sanitäts-Pol.*, Band i. p. 587.

Posen eat such meat with perfect indifference, and believe it is harmless when boiled.

With regard especially to *Erysipelas carbunculosum*, or black-quarter, as distinguished from malignant pustule (if it is to be so distinguished), Professor Gamgee [1] refers to cases of poisoning and two deaths mentioned to him by Dr Keith, of Aberdeen, caused by eating an animal affected with black-quarter. He also notices an instance which occurred "a number of years ago in Dumfriesshire," when seventeen persons were more or less affected, and at least one died, and states that a number of cases have been related to him by different observers.

The discrepancy of evidence is so great as to lead to the conclusion that the stage of the disease, or the part eaten, or the mode of cooking, must have great influence, and that a much more careful study than has yet been given to this subject is necessary to clear up these great variations of statement.

(*h*) *Splenic Apoplexy or Braxy of Sheep.*—Professor Simonds [2] states that pigs and dogs died in a few hours after eating the flesh of sheep dead of braxy. Professor Gamgee [3] affirms the same thing; but, on the other hand, Dr M'Gregor states that dogs eat the meat with perfect impunity. The experiments at Alfort [4] have also shown that pigs, dogs, and fowls are not incommoded by this poison, which yet acts violently when swallowed by sheep, goats, or horses. So also Dr Smith [5] states that the shepherds in the Highlands of Scotland eat by preference braxy sheep, and are quite healthy. Dr M'Gregor says that the flesh of braxy sheep is never cooked until it has been steeped for two months in brine, and then suspended for a time from the kitchen roof. It is preferred to ordinary salt mutton, because it has rather a flavour of game.

(*i*) *Smallpox of Sheep.*—The flesh has a peculiar nauseous smell, and is pale and moist. It produces sickness and diarrhœa, and sometimes febrile symptoms.

(*j*) *Foot-and-mouth Disease* (*Aphtha* (*or Eczema*) *epizootica*).—Lévy [6] states that at different times (1834, 1835, 1839) the aphthous disease has prevailed among cattle both at Paris and Lyons without the sale of the meat being interrupted or giving rise to bad results. The milk of cows affected with foot-and-mouth disease has been supposed to cause vesicular affection of the mouth in men.[7] The evidence seems, however, very uncertain. The discharges from the mouth are constantly on the hands of the farm labourers, who are not very cleanly, and who must constantly convey them to their own mouths, and yet these discharges, so infectious to other cattle, produce no effect on them.

(*k*) *Cattle Plague* (*Rinderpest, Typhus contagiosus of the French*).—*A priori*, such flesh would be considered highly dangerous, and the Belgian Academy of Medicine so consider it; but there is some strong evidence on the other side. In Strasbourg and in Paris, in 1814, many of the beasts eaten in those cities for several months had rinderpest, and yet no ill consequences were traced. But it may be questioned whether they were. looked for in that careful way they would be at the present day.[8] Some other

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[1] *Fifth Report of Medical Officer to the Privy Council*, p. 290.
[2] *Agricultural Journal*, No. 50, p. 232.
[3] *Privy Council Report*, 1863, p. 280.
[4] *Lévy*, t. ii. p. 631.
[5] *Social Science Trans.* for 1863, p. 559.
[6] *Traité d' Hygiène*, 1879, t. ii. p. 631.
[7] *Jour. of the Epid. Soc.*, vol. i. p. 423.
[8] The words of Coze (*Parent-Duchâtelet*, t. xi. p. 201) are, however, very strong. At Strasbourg, he says,—"Un millier de bœufs de grande taille, malades pour la plupart au plus haut dégré, puisqu'un assez grand nombre ont été égorgés au moment où ils allaient expirer, a été consommé, pendant et après le blocus, et cet aliment n'a produit aucune maladie."

evidence is stronger: Renault, the director of the Veterinary School at Alfort, made, for several years after 1882, many experiments, and asserts that there is no danger from the *cooked* flesh of cattle, pigs, or sheep dead of any contagious disease ("quelle que soit la répugnance bien naturelle que puissent inspirer ces produits").[1] So, also, during the occurrence of the rinderpest in England (1865), large quantities of the meat of animals killed in all stages of the disease were eaten without ill effects. In Bohemia also, in 1863, the peasants dug up the animals dead with rinderpest, and ate them without bad results.[2]

(*l*) *Rabies* in the dog and cow produce no bad effects.[3]

(*m*) Diseases in the pig, like *scarlet fever* and *pig typhus*, have prevailed in London, and the flesh has been eaten. No injury has been proved.[4]

(*n*) *Cysticercus cellulosæ* of the pig produces *Tænia solium*, and that of the ox and cow *Tænia mediocanellata*. These entozoa often arise from eating the raw meat, but neither cooking nor salting are quite preservative, though they may lessen the danger. Smoking appears to kill *Cysticerci*, and so, according to Delpech, does a temperature of 212° Fahr. T. Lewis[5] found that a much lower temperature sufficed. When *Cysticerci* had been exposed for five minutes to a heat of 130° Fahr. he could detect no movements, and he considered that a temperature of from 135° to 140° F. for five minutes would certainly kill them. Lewis considered there was no danger if the cooking were well done, as the temperature of well-done meat is never below 150° F.

(*o*) *Trichina spiralis* in the pig gives rise to the curious *Trichina* disease caused by the wanderings of the young *Trichinæ*. The affection is highly febrile, resembling enteric fever, or even typhus, or acute tuberculosis, but attended with excessive pains in the limbs and œdema.[6] Boils are also sometimes caused. The eating of raw trichiniferous pork is the chief cause, and the entozoon is not easily killed by cooking or salting. A temperature of 144° to 155° Fahr. kills free *Trichinæ*, but encapsuled *Trichinæ* may demand a greater heat (Fiedler). During cooking a temperature which will coagulate albumen (150° to 155° Fahr.) renders *Trichinæ* incapable of propagation, or destroys them. As a practical rule, it may be said that if the interior of a piece of boiled or roasted pork retains much of the blood-red colour of uncooked meat, the temperature has not been higher than 131° Fahr., and there is still danger. Intense cold and complete decomposition of the meat do not destroy *Trichinæ*.[7] Hot smoking, when thoroughly done, does destroy them (Leuckart); but the common kinds of smoking, when the heat is often low, do not touch *Trichinæ* (Küchenmeister).

(*p*) *Echinococcus Disease.*—It is well known that many persons will eat freely of, and even prefer, the liver of the sheep full of flukes. No direct evidence has been given of the production of disease from this cause, at least in this country. In Iceland *Echinococcus* disease, which affects a large

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[1] Payen, *Des Substances Alimentaires*, pp. 30, 31.

[2] Evidence of *Cattle Plague Commission*, question 997, and other places.

[3] *Parent-Duchâtelet*, t. ii. p. 197, cites a case of seven mad cows being sold without injury to those who ate the flesh.

[4] Letheby, *Chem. News*, Jan. 15, 1869.

[5] *The Bladder Worms found in Beef and Pork*, by T. R. Lewis, M.D., Calcutta, 1872.

[6] Aitken's *Practice of Medicine*, 7th edit., vol. i. p. 162. See also reports on Hygiene by the late Dr Parkes in the *Army Medical Reports* for 1860, 1861, 1862, and 1863, where references to most of the early cases will be found. See also Dr Thudichum's treatise in Mr Simon's *Report to the Privy Council*, 1864.

[7] Carré (*Comptes Rendus*, xcv. p. 147) says that they are destroyed at 40° to 50° below zero of Centigrade (= 40° to 58° below zero of Fahrenheit).

number of persons, is derived from sheep and cattle, who, in their turn, get the disease from *Tænia* of the dog (Leared and Krabbe).

(*q*) *Glanders* and *farcy* in horses do not appear to produce any injurious effects on their flesh when eaten as food. Parent-Duchâtelet[1] quotes two instances, in one of which 300 glandered horses were eaten without injury. In 1870, during the siege of Paris, large quantities of flesh from horses with farcy and glanders were eaten without injury.

(*r*) *Medicines*, especially *antimony*,[2] given to the animals in large quantities, have sometimes produced vomiting and diarrhœa. *Arsenic*, also, is occasionally given, and the flesh may contain enough arsenic to be dangerous.[3]

In time of peace, the duty of the army surgeon is simple. Under the terms of the contract, all sick beasts are necessarily excluded. Without reference, then, to any uncertain questions of hurtfulness, or the reverse, he must object to the use of the flesh of such animals. This is the safe and proper course.

But in time of war he may be placed in the dilemma of allowing such meat to be used or of getting none at all. He should then allow the issue of the meat of all animals ill with inflammatory and contagious diseases, with the exception of smallpox, and, perhaps, splenic apoplexy in sheep. But it will be well to take the precautions—1*st*, of bleeding the animals as thoroughly as possible; 2*nd*, of using only the muscles, and not the organs, as it is quite possible these may be more injurious than the muscles, though there are no decided facts on this point; and, 3*rd*, of seeing that the cooking is thoroughly done. But animals with smallpox, *Cysticerci*, and *Trichinæ* should not be used. If dire necessity compels their use, then the employment of a great heat in a baker's oven, and smoking if it can be used, may lessen the danger. If such things can be got, it would be well to try the effect on the meat of antiseptics, especially of carbolic acid, which destroys low animal life of that kind with great certainty.

Sub-Section IV.—Cooking of Meat.

Boiling.—The loss of weight is about 20 to 30 per cent., sometimes as much as 40. If it is wished to retain as much as possible of the salts and soluble substances in the meat, the piece should be left large, and should be plunged into boiling water for five minutes to coagulate the albumen. After this the heat can scarcely be too low. The temperature of coagulation of the albuminoid substances differs in the different constituents: one kind of albumen coagulates at as low a heat as 86° if the muscle serum be very acid; another albumen coagulates at 113° Fahr.; a large quantity of albumen coagulates at 167°; the hæmatoglobulin coagulates at 158° to 162°, below which temperature the meat will be underdone. If the temperature is kept above 170° the muscular tissue shrinks, and becomes hard and indigestible. Liebig recommends a temperature of 158° to 160°. Most military cooks employ too great a heat: the meat is shrunken and hard. In boiling, ammonium sulphide is evolved, with odoriferous compounds, and an acid like acetic acid.

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[1] *Hyg. Publ.*, t. ii. 194; see also Lévy, t. ii. p. 630.

[2] See a well-marked case cited by Pavy (*A Treatise on Food and Dietetics*, 2d ed., 1875, p. 160), as quoted by Gamgee, from the *Central Zeitung für die gessammte Veterinärmedizin für* 1854, where 107 persons were attacked after eating the flesh of an ox which had been treated with tartar-emetic previous to being slaughtered.

[3] Lévy, *Traité d'Hygiène*, 1879, t. ii. pp. 663-64; reference to experiments of Danger, Flandin, and Chatin.

If it is desired to make good broth, the meat is cut small, and put into cold water, and then warmed to 150° F.; beef gives the weakest broth. In a pint there are about 150 grains of organic matter, and 90 grains of salts. Mutton broth is a little stronger, and chicken broth strongest of all. About 82 per cent. of the salts of beef pass into the broth, viz., all the chlorides, and most of the phosphates.

Broth made without heat, by the addition of four drops of hydrochloric acid to a pint of water and half a pound of beef, is richer in soluble albumen. Lactic acid and chloride of potassium added together have the same effect. If rather more hydrochloric acid be used but no salt, heat can be applied; and, if not higher than 130° Fahr., nearly 50 per cent. of the meat can be obtained in the broth.

Roasting.—The loss varies from 20 to 35 per cent.; in beef, it is rather less than in mutton (Oesterlen). This loss is chiefly water; the proportion of carbon, hydrogen, nitrogen, and oxygen remaining the same (Playfair). Roasting should be slowly done; to retain the juices, the meat must be first subjected to an intense heat, and afterwards cooked very slowly; the dry distillation forms aromatic products, which are in part volatilised; the fat is in part melted, and flows out with gelatin and altered extractive matters. The fat often, improperly, becomes the perquisite of the cook, and may be lost to the soldier. The loss in baking is nearly the same, or a little less.

Stewing.—This is virtually the same as roasting, only the meat is cut up, is continually moistened with its own juices, and is often mixed with vegetables. Like boiling and roasting, it should be done slowly at a low heat; the loss then is about 20 per cent., and chiefly water.

In all cases there is one grand rule, viz., to cook the meat slowly, and with little heat, and, as far as possible, to let the loss be water only. The fault in military kitchens has been, that excessive heat is used. The meat is then often a sodden, tasteless mass, with hard, shrunken, and indigestible fibres. The thermometer will be found very useful, especially in showing cooks that the temperature is much higher than they think. In the cooking of salt meat the heat should be very slowly applied and long continued; it is said that the addition of a little vinegar softens the hard sarcolemma, and it is certain that vinegar is an agreeable condiment to take with salt meat, and is probably very useful. It may be of importance to remember this in time of war.

In cutting up meat there is a loss of about 5 per cent., and there is also a loss from bone, so that, all deductions being made, the soldier does not get more than 5 or 6 ounces of cooked meat out of 12 ounces.

The large quantity of flesh extract contained in the brine can be obtained by dialysis; from two gallons of brine a fluid has been obtained, which, on evaporation, yielded 1 ℔ of extract.[1]

Sub-Section V.—Preservation of Meat.

Meat may be kept for some time by simply heating the outside very strongly, so as to coagulate the albumen; or by placing it in a close vessel, in which sulphur is burnt, or by covering the surface with charcoal, or strong acetic acid, or calcium disulphide, or weak carbolic acid. Injections of alum and aluminum chloride through the vessels will preserve it for a long time; water should be injected first, and then the solution. Even common salt in-

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[1] Whitelaw, *Chemical News*, March 1864.

jected in the same way will keep it for some time. So also will free exposure to pure air; charcoal thrown over it, and suspended also in the air; or, the meat being cut into smaller portions, and placed in a large vessel, heat should be applied, and, while hot, the mouth of the vessel should be closed tightly with well washed and dried cotton wool; the air is filtered, and partially freed from germs. The application of sugar to the surface is also a good plan. Cold is a great preservative of meat; in ice it can be preserved for an unlimited period, and the supposed rapid decomposition after thawing seems to have been exaggerated.[1] Fresh meat is now largely imported from America and Australia by being kept in refrigerated chambers.

Plans of this kind may be useful to medical officers under two circumstances, viz., on board ship, and in sieges, when it is of importance to preserve every portion of food as long as possible. The covering the whole surface with powdered charcoal is perhaps as convenient as any plan. A coating of paraffin, and many other plans of excluding air, are also used.

Meat is also preserved in tin cases, either simply by the complete exclusion of air (Appert's process) or by partly excluding air and destroying the oxygen of the remaining part by sodium sulphite (M'Call's process). It is not necessary to raise the heat so high in this case, and the meat is less sapid. Meat prepared in either way has, it is said, given rise to diarrhœa, but this is simply from bad preparation: when well manufactured it has not this effect.

Meat is also preserved by drawing off the air from the case, and substituting nitrogen and a little sulphur dioxide (Jones and Trevithick's patent), or the air can be heated to 400° or 500°, so as to kill all germs (Pasteur), and then allowed to flow into an exhausted flask.[2]

Various other plans have been proposed, such as the use of antiseptics, carbolic acid (?), borax, boric acid, salicylic acid, glycerin, &c., and various preparations such as glacialin, boro-glyceride, and the like, consisting of mixtures of two or more. Of the preparations, boric acid and glycerin appear to be the most useful and least hurtful; but salicylic acid and salicylates are unadvisable on account of their depressing action.

SECTION II.

WHEAT.

Advantages as an Article of Diet.—It is poor in water and rich in solids, therefore very nutritious in small bulk; when the two outer coats are separated, the whole grain is digestible. The nitrogenous substances are large and varied,[3] consisting of soluble albumen (1 to 2 per cent.) and glutin (8 to 12 per cent,), which itself consists of four substances, named by Ritthausen,[4] glutin-casein, gliadin (or vegetable gelatin), glutin-fibrin, and mucedin. The starchy substances (starch, dextrin, sugar) are large, 60 to 70 per cent., and are easily digested; and, according to Mége-Mouriès, a nitrogenous substance (cerealin) is contained in the internal envelope,

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[1] Bonley, *Comptes Rendus*, xcv. p. 147.

[2] Dr Letheby's Cantor *Lectures on Food*, delivered before the Society of Arts in 1869, 2nd edition, 1872, give a good account of some of the patents for the preservation of meat. See also Meinert, *Armee- und Volks-Ernährung*. Berlin, 1880, vol. ii. p. 265; also Renk, *Conservirung von Nahrungsmitteln, Deutsche Vierteljahrschr. f. öff. Gesundheitspfl.*, Band xiii. Heft 1.

[3] These reach 14 to 15 per cent., especially in the hard wheats of Italy and Sicily, which are used for macaroni (Letheby).

[4] *Die Eiweisskörper der Getreidearten*, von Dr H. Ritthausen, 1872.

which, like diastase, acts energetically in transforming starch into dextrin, sugar, and lactic acid. Some consider this cerealin to be merely a form of diastase. Cholesterin is found in wheat, but in very small quantity (Ritthausen). The salts are chiefly phosphates of potash and magnesia.

Disadvantages.—It is deficient in fat, and in vegetable salts which may form carbonates in the system.

As usually prepared, the grain is separated into flour and bran; the mean being 80 parts of flour, 16 of bran, and 4 of loss. The flour is itself divided into best or superfine, seconds or middlings, pollards or thirds or bran flour. In different districts different names are used. The wheats of commerce are named from colour or consistence (hard or soft, white or red); the hard wheat contains less water, less starch, and more glutin than the soft wheat.

Sub-Section I.—Wheat Grains.

The medical officer will seldom be called on to examine wheat grains, but if so, the following points should be attended to. The grains should be well filled out, of not too dark a colour; the furrow should not be too deep; there should be no smell, no discoloration, and no evidence of insects or *fungi.* The heavier the weight the better. In the Belgian army the minimum weight is 77 kilogrammes the hectolitre.[1] In England, good wheat weighs 60 ℔ to the bushel; light wheat 58 ℔ or even 50 ℔. *Fungi*, if present, will be found at the roots of the hairs, and if in small amount are only microscopic. If in large amount they cause the diseases known by the name of rust, bunt or smut, or dust brand; they are owing to species of *Uredo* and *Puccinia.* If any grains are seen pierced with a hole, and on examination are found to be a mere shell, with all the starch gone, this is owing to the weevil, and the little insect can itself be found readily enough if a handful of wheat be taken and spread over a large plate. The weevil can hardly escape being seen. *Acarus farinæ* may also prey on the wheat grain, but cannot be seen without a microscope.

Sub-Section II.—Flour.

Almost all the bran is separated from the finest flour; it has been a question whether this is desirable, as the bran contains nitrogenous matter —as much sometimes as 15 per cent., with 3·5 per cent. of fat, and 5·7 per cent. of salts. But if the bran is used, it seems probable that much is left undigested, and all the nutriment which is contained in it is not extracted. A plan has been employed by Mége-Mouriès, which seems to save all the most valuable parts of the bran; the two or three outer and more or less siliceous envelopes of the wheat are detached, and the fourth or internal envelope is left. Several plans of decorticating wheat have been proposed, but none of them at present have superseded the old system of grinding.

If the whole wheat is used, it should be ground very fine, as the harder envelopes are irritating, and it is well to remember that for sick persons with any bowel complaints bread must be used entirely without bran. Dysenteries have been found most intractable, merely from attention not being directed to this simple point. It is all the more necessary to insist upon this, as whole-meal bread has been much recommended and used of late. At the same time there is no doubt that whole-meal bread, well made, is more nutritious than the fine white bread now so generally used. The

[1] Squillier, *Des Subsist. Mil.*, p. 37.

principal constituents lost with the bran are fat and salts, the analysis of whole meal showing a marked excess of these over best sifted flour. The average of a number of samples of flour examined at Netley showed only 1·3 of fat, instead of 2, as in the table (p. 243), and 0·91 of salts; some very fine Russian flour yielded under 0·6 of salts, against 1·7 in the table. It is clear that these numbers are too high for finely-sifted flour. There is also a certain loss of nitrogenous matter, some of which is believed to aid digestion. But for the irritating qualities of the outer envelopes (which have, however, been much diminished by modern processes), whole-meal bread would be a more valuable nutrient.

For the CHEMICAL examination of Flour, see BOOK III.

Microscopical Examination.

This is especially directed to determine the relative amount of flour and bran, the presence of *fungi* or *acari*, or the fact of adulteration by other grains.

In examining wheat, or any other cereal grains, it is necessary to prepare them beforehand by soaking for some time in water. It will then be found easy to demonstrate the different structures. By means of a needle and a pair of fine forceps the different coats can be removed *seriatim*, sometimes quite separately, but generally more or less in combination. The only one that presents any difficulty is the third coat of wheat or barley, but generally it can be found accompanying the second or fourth coats. In the case of barley, the proper external envelope of the grain sometimes adheres to the interior of the husk, where it ought to be looked for in the event of its not being on the surface of the grain itself. After examining the separate coats, sections may be made of the whole grain, so as to see the structures *in situ*. The hairs are generally found in a bunch at the end of the grain. The starch grains are best demonstrated by picking out a little from the centre of the grain; glycerin mixed with water forms the best medium for demonstration.

Structure of the Wheat Grain.—There are four envelopes (some authors

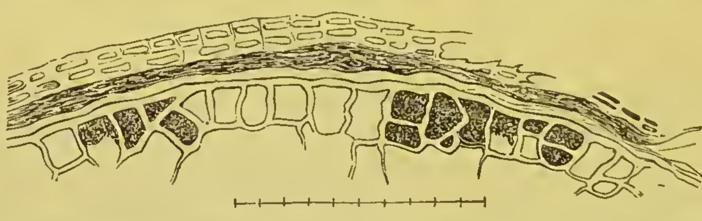


Fig. 45.—Transverse Section of Envelopes of Wheat. Scale 1000th of an inch.

make five or six—the outer coat being divided into two or three) surrounding a fine and very loose areolar tissue of cellulose filled with starch grains.

Envelopes of Wheat.—The drawings show the coats *in situ*, cut transversely

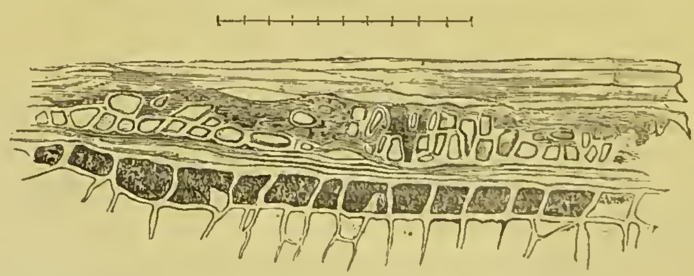


Fig. 46. Envelopes of Wheat (longitudinal section). Scale 1000th of an inch.

and longitudinally, also the separate coats. The outer coat is made up of two or three layers of long cells, with slightly beaded walls, running in the direction of the axis of the grain. The septa are straight or oblique, and,

Fig. 47.—Outer Coat and Hairs of Wheat. Scale 100th of an inch.

as will be seen, the cells differ in length and breadth. The size can be taken by the scale. The hairs are attached to this coat, and are prolongations, in fact, of the cells. In the finest flour the hairs and bits of this coat (as well as of the other coats) can be found.

The second coat, counting from without, is composed of a layer of shorter cells, more regular in size, with slightly rounded ends and beaded walls, and lying at right angles to the first coat, or across the axis of the grain. It is impossible to mistake it. The third coat is a delicate diaphanous, almost

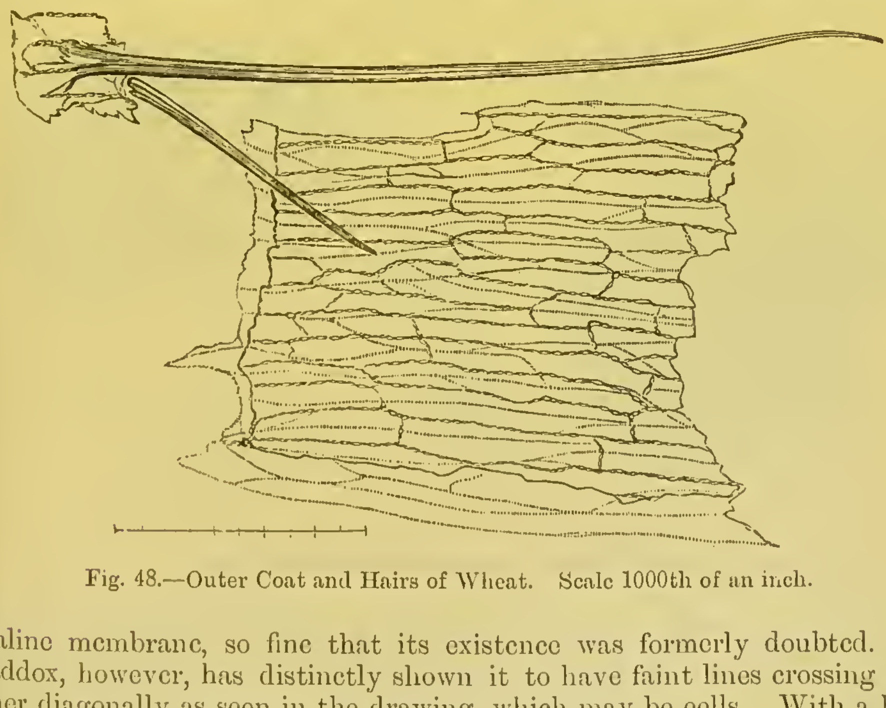


Fig. 48.—Outer Coat and Hairs of Wheat. Scale 1000th of an inch.

hyaline membrane, so fine that its existence was formerly doubted. Dr Maddox, however, has distinctly shown it to have faint lines crossing each other diagonally as seen in the drawing, which may be cells. With a little care, it is very easily demonstrated. In the transverse section of the

envelope it appears as a thin white line. Internal, again, to this coat what appears to be another coat can sometimes be made out: it is a very fine membrane, marked with widely separated curved lines, which look like the

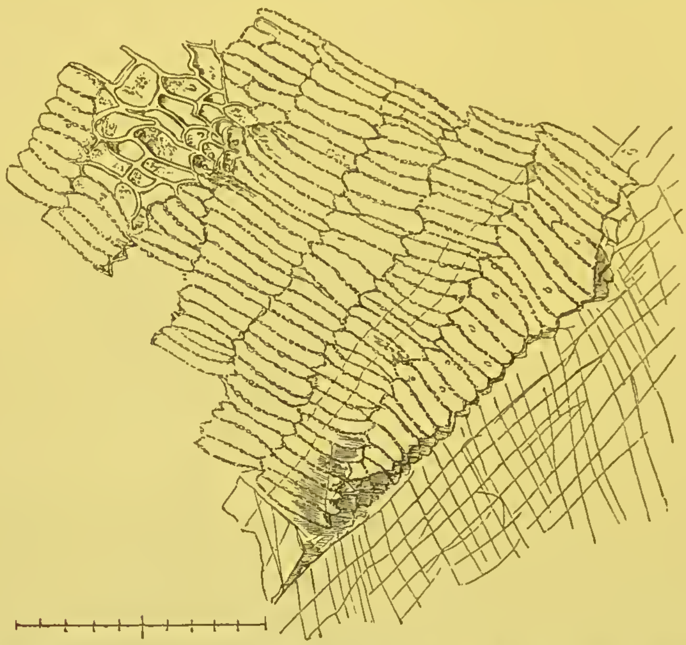


Fig. 49.—Second and Third Envelopes of Wheat. Scale 1000th of an inch.

outlines of large round or oval cells. The internal or fourth coat, as it is usually called, is composed of one or two layers (in places) of rounded or squarish cells filled with a dark substance which can be emptied from the cells. When the cells are empty, they have a remote resemblance to the

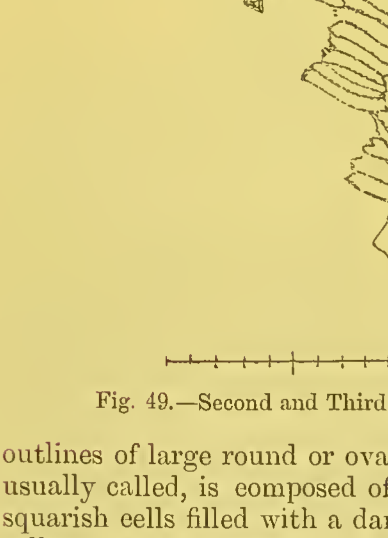


Fig. 50.—Fourth Envelope of Wheat. Scale 1000th of an inch.

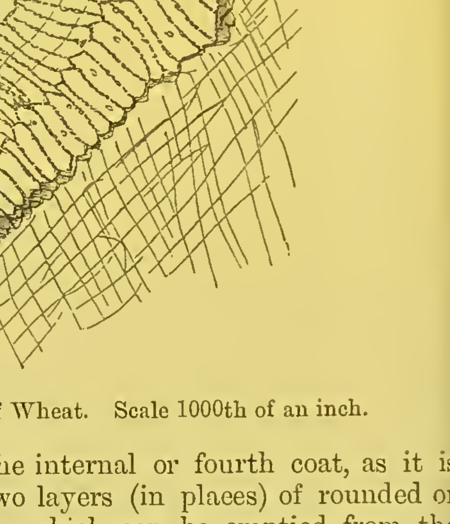


Fig. 51.—Fresh Starch Grains of Wheat (moistened). × 360.

areolar tissue of the leguminosæ, and there is little doubt that from this cause adulteration with pea or bean has been sometimes improperly asserted.

The starch grains of wheat are very variable in size, the smallest being

almost mere points, the largest $\frac{1}{1000}$th of an inch in diameter or larger. In shape the smallest are round, the largest round oval, or lenticular. It has been well noticed by Hassall that there is often a singular want of intermediate-sized grains. The hilum, when it can be seen, is central, the

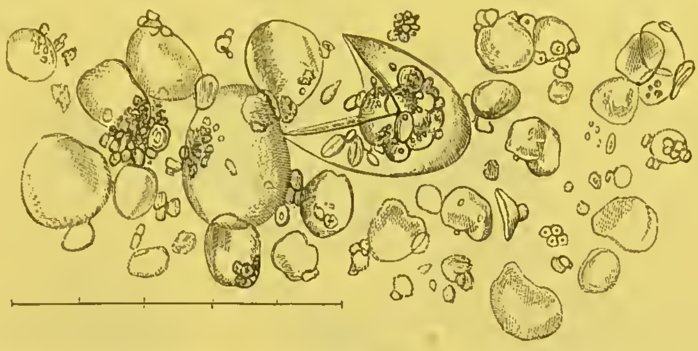


Fig. 52.—Dried and then moistened Starch Grains of Wheat. Scale 1000th of an inch.

concentric lines are perceived with difficulty, and only in a small number; the edge of the grain is sometimes turned over so as to cause the appearance of a slight furrow or line along the grain. Very weak liquor potassæ causes little swellings; strong liquor potassæ bulges them out, and eventually destroys them. There is no difficulty in seeing if the pieces of envelope are too numerous, but it should be remembered the best flour contains some.

Diseases of Flour.

Fungi.—Several *fungi* are found in wheat flour. The most common fungus is a species of *Puccinia.* It is easily recognised by its round dark sporangia, which are either contoured with a double line, or are covered with little projections. It is said not to be injurious by some, but this is very doubtful. The symptoms have not been well described.

The smut, or caries, is also a species of *Puccinia;* has large sporules, and

Fig. 53.—Diseased Flour (*Puccinia*).

gives a disagreeable smell to the flour and a bluish colour to the bread. It is said to produce diarrhœa.

Acarus.—*Acarus farinæ* is by no means uncommon in inferior flour, especially if it is damp. It does not necessarily indicate that leguminous seeds are present, as stated. It is no doubt introduced from the grain in

the mill, as it has been found adhering to the grain itself. It is at once recognised. Portions of the skin are also sometimes found.

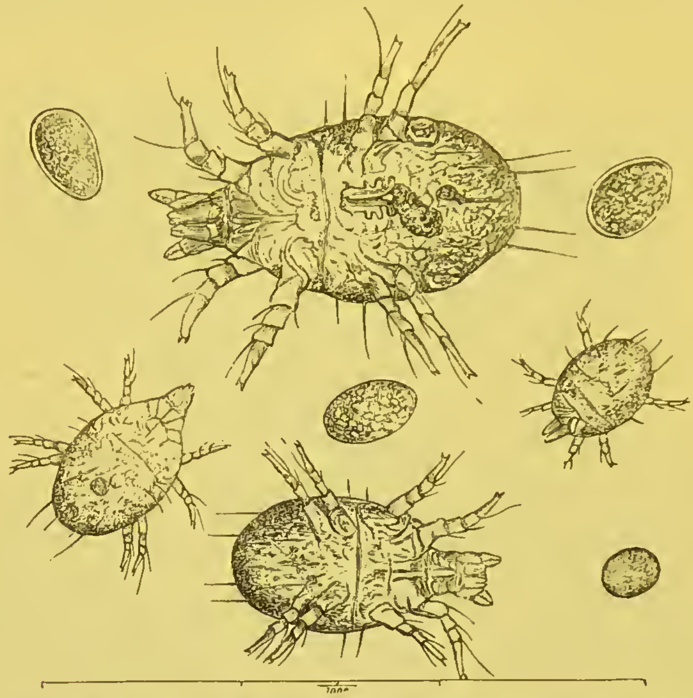


Fig. 54.—*Acarus farinæ* (× 85 diameters).—Mites found in flour alive. In the largest figures the insects are considerably compressed, to show the powerful mandibles, and have each a ventral aspect. In the smallest and middle-sized insect we have drawn the dorsal aspect; the former only possesses six legs, as before the first moult; several ova lie scattered in the field of view. It is unknown what office the capsular organs fulfil. They are well seen on each side of the largest figure.

Vibriones.—These form for the most part in flour which has gone to extreme decomposition, and is moist and becoming discoloured. They cannot be mistaken.

The presence of *Acari* always shows that the flour is beginning to change.

Fig. 55.
Weevil—Natural size.

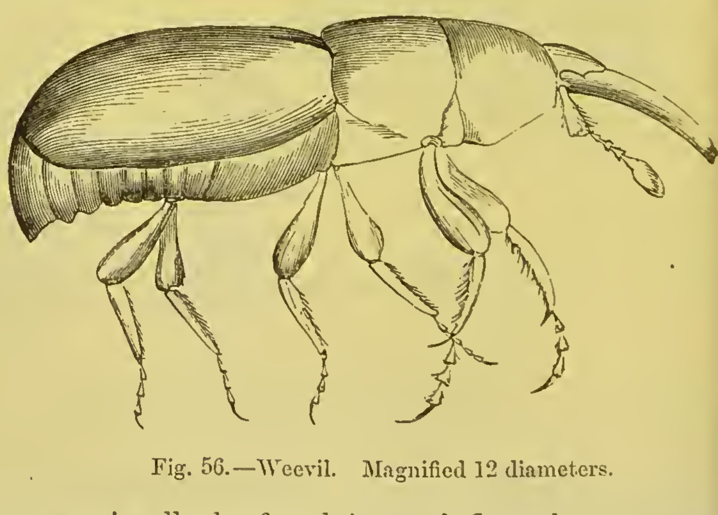


Fig. 56.—Weevil. Magnified 12 diameters.

A single *acarus* may occasionally be found in good flour, but even one should be looked on with suspicion, and the flour should be afterwards frequently examined to see if they are increasing.

Weevil (*Calandra granaria*).—The weevil is of course at once detected. It is by no means so common in flour as in corn.

Ephestia.—The larva of the moth which feeds on cocoa (*Ephestia elutella*) has sometimes caused great ravages in flour and in biscuits. At Cork and Gibraltar many tons of biscuit have been rendered useless by this larva, which appears to have been introduced from the cocoa stored for the fleet [1]

Adulterations of Wheat-Flour.

At present there is very little adulteration of wheat-flour in this country, but with rising prices the case might be different. Abroad, adulteration is probably more common, and the medical officer must be prepared to investigate the point.

The chief adulterations are by the flour of other grains, viz.:—

Barley,	Rice,	in some countries,
Potato,	Buckwheat,	
Beans and peas,	Millet,	
Maize,	Linseed,	
Oat,	Melampyrum,	
Rye,	Lolium,	

and other grains noticed farther on. All these are easily recognised by the microscope.

Other adulterations are by mineral substances, viz.:—

Alum,	Powdered flint,
Gypsum,	Calcium and magnesium
Clay,	carbonate.

These are best detected by chemical examination.

Detection of Barley.—This is not easy, but can, with care, be often done.

The envelopes of barley are the same in number as those of wheat, but they are more delicate. The outer coat has three layers of cells; the walls of the external layer are beautifully waved, but not beaded; the cells are smaller than those of the outer coat of wheat. The second coat, disposed at right angles to the first, as in wheat, is like the second coat of wheat, except in being more delicate and not beaded. The third is hyaline and transparent, with faint cross-lines, as in wheat. The fourth has the cells similar in shape to the corresponding wheat coat, but they are very much smaller, as may be seen on reference to the scale, and there are two or often three layers.

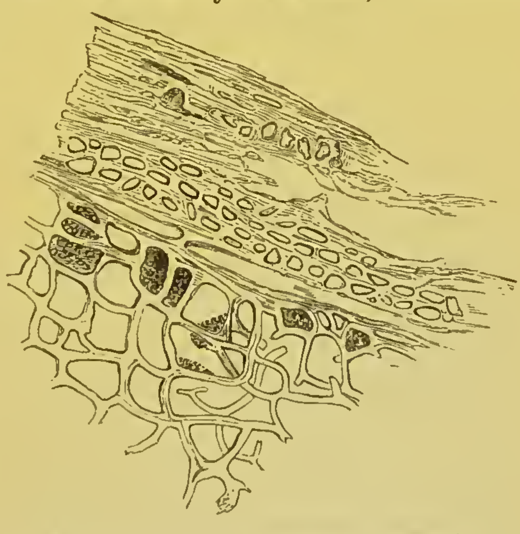


Fig. 57.—Barley (longitudinal section). Scale is the same as that of the Starch Grains.

The *starch grains* of barley are very like the wheat, with a central hilum and obscure marking, but are on the whole smaller; some have thickened edges, instead of the thin edges of the wheat-starch grains, but it is very difficult and sometimes impossible to distinguish them. It is therefore specially to the envelopes that we must attend.

[1] Professor Huxley has kindly given these interesting details. The larva of *Ephestia elutella* (or "chocolate moth") is small, and is never more than half an inch long. The

Detection of Potato Starch.—This is a matter of no difficulty; the starch grains, instead of being round or oval, and with a central hilum and obscure rings, are pyriform, with an eccentric hilum placed at the smaller end, and with well-marked concentric rings. Weak liquor potassæ (1 drop of liq. pot. B.P. to 10 of water) swells them out greatly after a time, while wheat-starch is little affected by this strength; if the strength is 1 to 3 (as in the figure), the swelling is very rapid.

Detection of Maize (*Indian Corn*).—There are two envelopes; the outer being made up of seven or eight strata of cells; there is no transverse

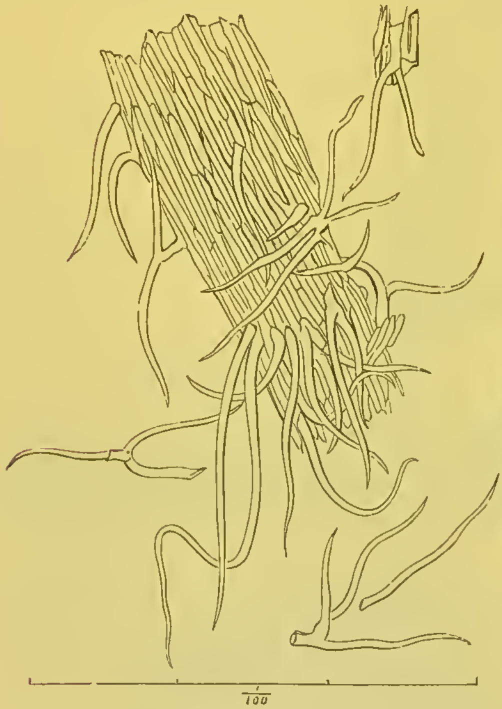


Fig. 58.
Outer Coat and Hairs of Barley (low power).

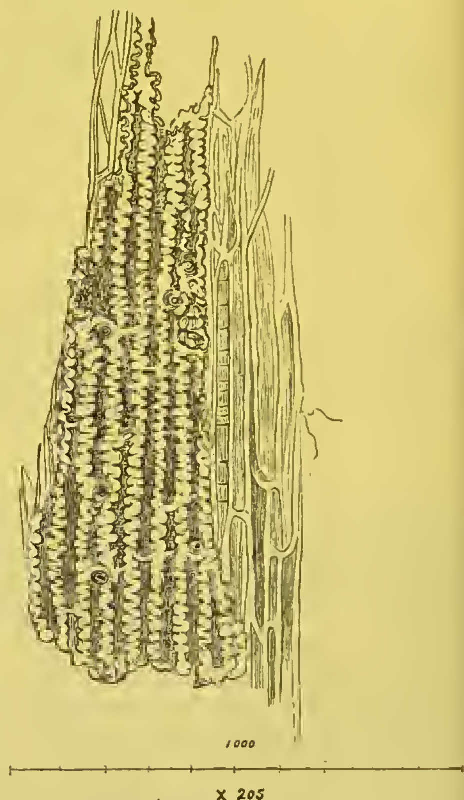


Fig. 59.
Outer Coat of Barley (higher power).

second coat, as in wheat; the internal coat consists of a single stratum of cells like the fourth of wheat, but less regular in shape and size. The cellulose, through the seed holding the starch in its meshes, forms a very characteristic structure, which on section looks like a pavement made of triangular, square, or polygonal pieces; the cells are filled with the starch

female moths fly at night in swarms, and lay their eggs on the biscuits or the puncheons which hold them. The larvæ are soon hatched, and by means of strong jaws and active legs scrape and bore their way through crevices; they eat the biscuit, and spoil more than they eat by spinning their webs over the biscuit. Cocoa stores swarm with the moths and larvæ, and they even penetrated into many parts of H.M.S. "Hercules."

After examining into the ravages caused by these larvæ in the biscuit at Gibraltar, Mr Huxley made the following suggestions :—

1. To have no cocoa stored in any place in which biscuits are manufactured.
2. To head up all biscuit puncheons as soon as they are full of the freshly baked biscuit.
3. Coat puncheons with tar after they are headed up, or at least work lime wash well into all the joints and crevices.
4. Line the bread-rooms of ships with tin, so that if the *Ephestia* has got into a puncheon it may not get into the rest of the ship.
5. If other means fail, expose woodwork of puncheons to a heat of 200° Fahr. for two hours.

grains, which are very small, and compressed, so as to have facets. They are very different from the smooth, uncompressed round cells of wheat.

Bits of cellulose, with its peculiar angular markings, are always found if the wheat is adulterated with maize.

Detection of Bean and Pea.—These adulterations are also at once discovered; the meshes of cellulose are very much larger than those of the fourth

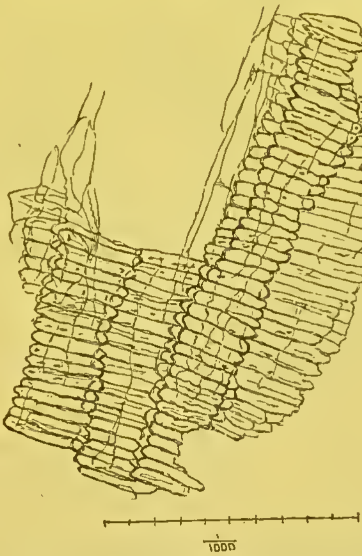


Fig. 60.—Barley (second and third coats).

coat of wheat, with which it has sometimes been confounded, and the starch grains are also quite different; they are oval or reniform, or with one end slightly larger; they have no clear hilum or rings, but many have a deep central longitudinal cleft running in the longer axis, and occupying two-thirds

Fig. 61.—Barley (fourth coat).

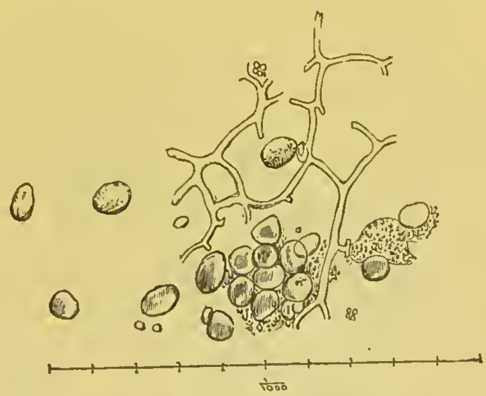


Fig. 62.—Barley (Starch Grains).

or three-fourths of the length, but never reaching completely to the end; this cleft is sometimes a line, sometimes almost a chasm, and occasionally secondary clefts abut upon it at parts of its course; sometimes, instead of a cleft, there is an irregular-shaped depression. If a little liquor potassæ be added, the cellulose is seen more clearly. Pea-flour is never added to a greater extent than 4 per cent., as it makes the bread heavy and dark. If the flour be mixed with a little boiling water, the smell of the pea or bean is perceptible.

Detection of Oat.—There are two or three envelopes; the outer longitudinal cells; the second obliquely transverse, and not very clearly seen; the cells are

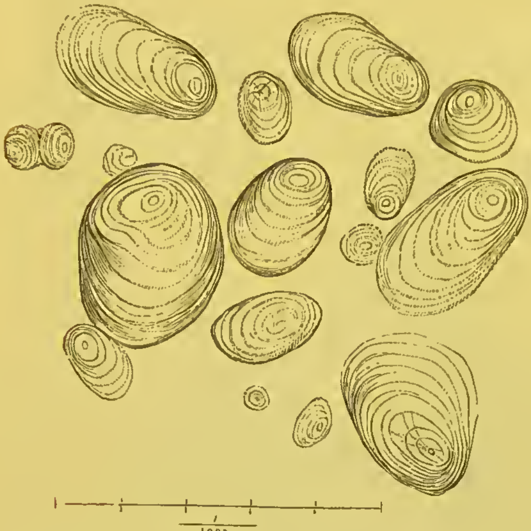
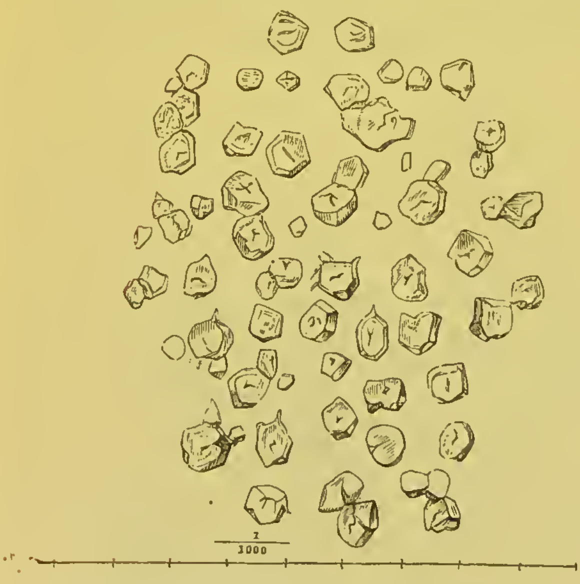


Fig. 63.—Potato Starch. × 285. See also Plate of Starches.

Fig. 64.—Medium and small-sized Potato Starch Grains, treated with Liq. Pot. B.P. (strength 1 to 3), and × 285.

wanting in parts, or pass into the cells of the third coat; the third a layer, usually single, of cells like the fourth coat of wheat. The husk must be detached before the envelopes are looked for, for lining it is a layer of wavy cells, like the external envelope of barley, which might mislead. The starch-



×250

Fig. 65.—Indian-Corn Flour. See also Plate of Starches.

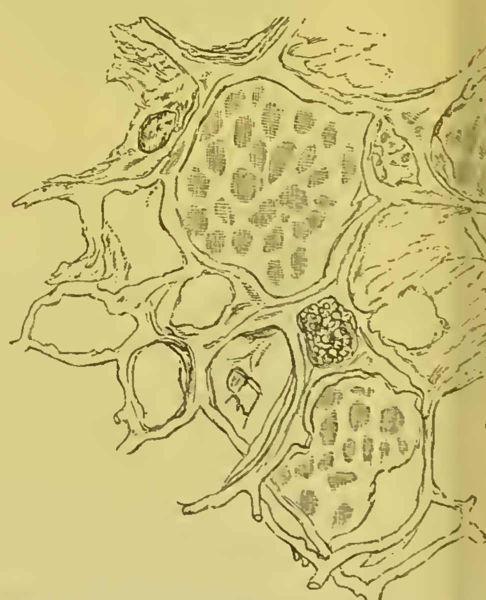


Fig. 66.—Cellulose of Indian Corn × 500, with markings from the Starch Grains on the intercellular membrane.

cells are small, many-sided, and cohere into composite round bodies, which are very characteristic, and which can be broken down into the separate grains by pressure. A high power is the best for this. The oat starch does

not polarise light. There is no difficulty in the detection of the starch grains.

Detection of Rice.—The husk of rice is very peculiar; on the outer coat are numerous siliceous granules, arranged in longitudinal and transverse

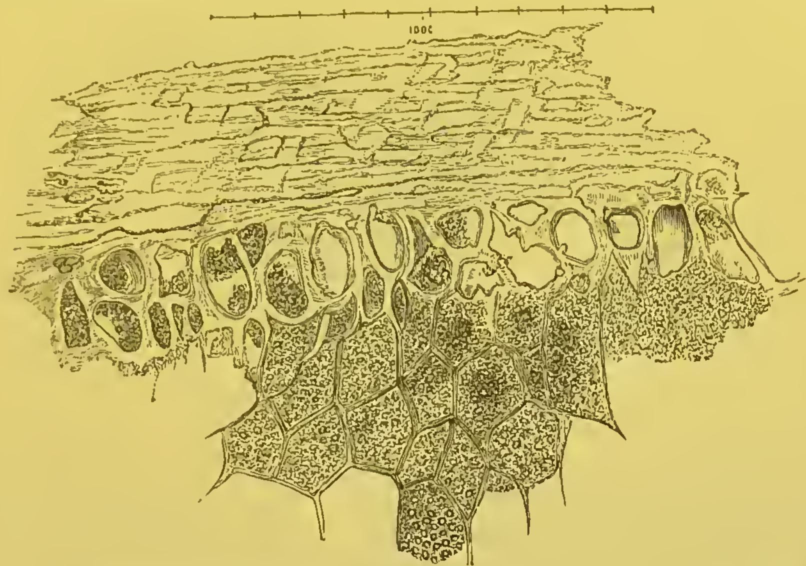


Fig. 67.—Longitudinal Section of Coats of Indian Corn and Cellulose. × 190.

ridges (figs. 72 and 73) (*a*). There are numerous hairs, some of which are seated over stomata. Below this is a membrane of transverse and longitudinal rough-edged fibres (*b*, *c*), while below these again is a fine membrane of

Fig. 68.—Bean Starch.

transverse angular cells (*d*), covering a very delicate membrane of large cells. The starch corpuscles are very small (fig. 71); angular under low powers; under high powers they are seen to be facetted and compressed. They can-

not be mistaken for the round cells of wheat, but may be confounded with oat starch, from which, however, they are distinguished by the absence of the compound cells or glomeruli. Their shape is also a little like maize, but they are very much smaller.

Fig. 69.—Pea Flour.

Detection of Rye.—The envelopes are very like those of wheat, and can perhaps hardly be distinguished from them. The recent starch grains are also like those of wheat, but they are much more distinctly spherical. They have also sometimes a peculiar rayed hilum, which used to be thought

Fig. 70.—White Oat (long. sect., 2nd and 3rd coats not separable). *a*, Compound grains × 100. *b*, One do. × 500.

peculiar to the older and drier grains. It is, however, to be seen even in the starch of fresh soft grains, whilst the plant is still green. In the starch of wheat it is only met with occasionally, when the grain is very old or dry.

Rye, if in any quantity, is discovered by baking; it makes a dark, acid bread.

Fig. 71.—Ground Rice Flour. × 350.

Linseed is not a common adulterant. The envelopes are peculiar: the external is made up of hexagonal cells containing oil; the second of round

Fig. 72.—Rice. × 170. Fig. 73.—Rice. × 188.

Fig. 72. Transverse section of the Husk of Rice. } × 170.
Fig. 73. Appearance of Husk as seen in a transparent medium of glycerin and gum. }
a, Siliceous granules, arranged in longitudinal and transverse ridges, perforated by openings—stomata, some having hairs seated over them. *b*, *c*, Transverse and longitudinal, brittle, rough-edged fibres. *d*, A fine membrane of transverse angular cells; these overlie a very delicate membrane of large cells *e*.

cells; the third of fibres; and the fourth of angular cells containing a dark reddish colouring matter.

Buckwheat (*Polygonum Fagopyrum*, or *Fagopyrum esculentum*).—Like rye, this is only likely to be found in wheat coming from the Baltic. The drawing sufficiently shows the texture of the envelopes, which is very complicated. The starch grains are small and round, and adhere together in masses. Under a high power there are indications of concentric rings. Bread made with this grain has a darkish, somewhat violet, colour.

Millet.—In India, Egypt, China, and West Coast of Africa, millet of some kind is likely to be an adulteration. Dr Maddox's drawing (page 286) shows the beautiful structure of the envelopes, which could not be confounded with those of wheat. The starch grains are very small, round, and tolerably uniform in size.

Melampyrum arvense and other species (Purple cow-wheat — *Scrophulariaceæ*).—This has occasionally been mixed with flour; it is not injurious, but gives the bread (not the flour) a peculiar smoky violet or bluish-violet tint. This depends on a colouring matter in the seed, which, when warmed with acid, gives the violet colour.[1]

Trifolium arvense (Trefoil — *Leguminosæ*).—This also gives the bread a red-violet colour. It is not known to be injurious.

Fig. 74.—Rye Starch, with rayed hilum (after Hassall). × 420.

Fig. 75.—Rye—1, Transverse section of Testa, &c. × 108; 2, Coats *in situ* from without, × 170. *a*, External; *b*, Middle; *c*, Internal coat; *d*, Starch grains, × 108.

Rhinanthus major and *crista galli* (Yellow-rattle—*Scrophulariaceæ*) gives

[1] Pellischek, *Schmidt's Jahrb.*, 1863, No. 3, p. 287.

bread a bluish-black colour, a moist sticky feel, and a disagreeable sweet taste. It is not injurious. *Onobrychis sativa* (Sainfoin—*Leguminosæ*) has also been used.

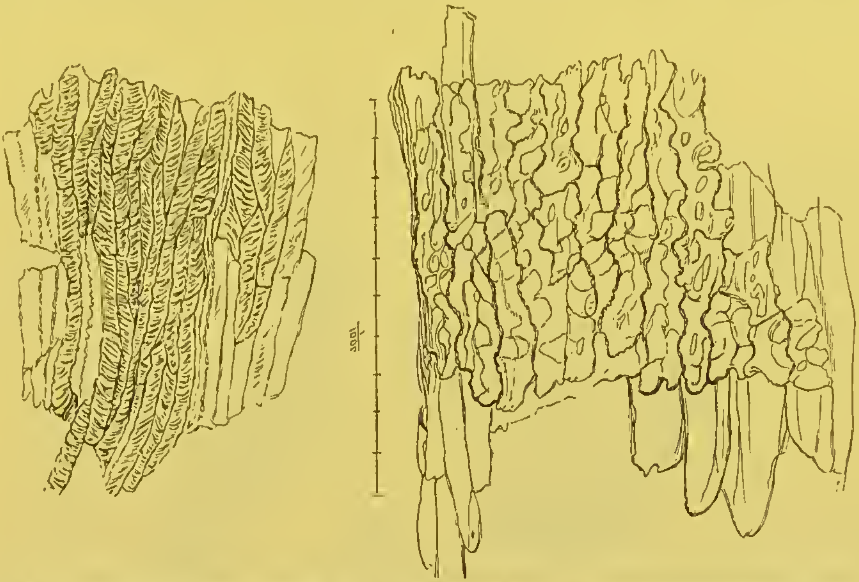


Fig. 76.—Outer coat of Buckwheat, apparently of irregular and interlacing fibrospiral cells, separable by boiling the testa and macerating it. Outside these cells is a very thin and delicate membrane, retaining the marks of attachment of the spiral cells. × 170.

Internal coats. The most internal is composed of cells with an irregular waved outline, and longitudinal cells over the starch cells. × 170.

Fig. 77.—Buckwheat—Transverse section of outer, middle, and internal coats, with cellulose containing starch grains, . . . } × 170. Starch grains, × 500.

Lolium temulentum (Darnel—*Gramineæ;* other species may be used).—This gives the bread no colour, but produces narcotic symptoms, vertigo, hallucinations, delirium, convulsions, and paralysis.[1] Pellischek states that these symptoms do not occur if the grain be dried in an oven before baking,

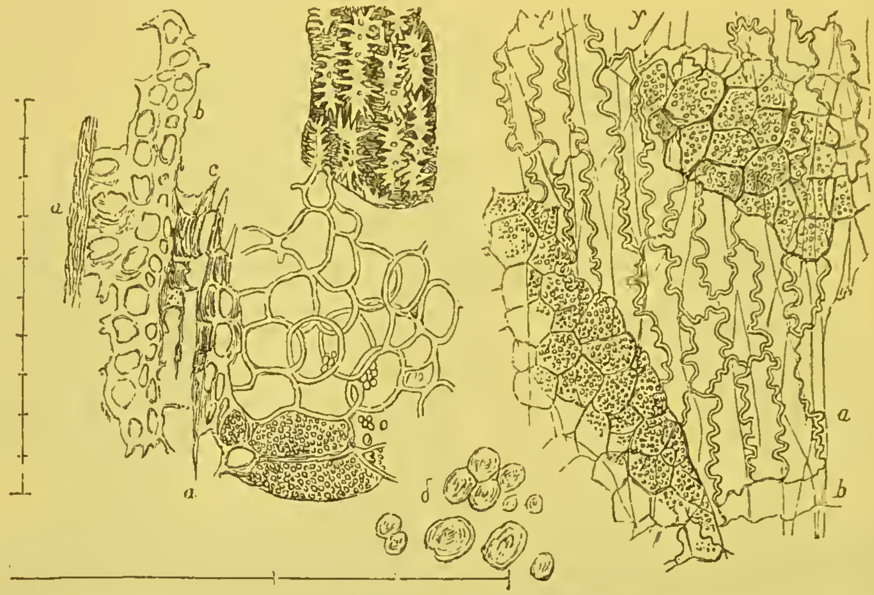


Fig. 78.—Millet Seed—*a*, Transverse section of testa coats, seen from inside; *a*, Outer; *b*, Middle; *c*, Inner coat × 170; *δ*, Starch grains × 500. Scale 1-1000th inch.

or if the bread is left for some days before being used. Under the name of "Drake," Darnel grass seed appears to be an accidental adulteration of the poorer Australian flours. This has been detected by Dr Davidson, of the Mauritius, in flour imported into that colony from Australia. Samples of "Drake" sent by him have been found by Professor Thistleton Dyer to be identical with Darnel seed. The detection of *lolium* is best effected by means of alcohol, which gives a greenish solution with a disagreeable repulsive taste, and on evaporation a resinous yellow-green disagreeable extract is left. Pure flour gives with alcohol only a clear straw-coloured

[1] The peculiar symptoms produced by *Lolium temulentum*, or bearded Darnel, were well known to the ancients. Pereira states that the first symptoms are gastro-intestinal, such as vomiting and colic, and then cerebro-spinal symptoms come on, viz., headache, giddiness, tinnitus, confusion of sight, dilated pupils, delirium, trembling and paralysis (*Elements of Materia Medica*, 1850, vol. ii. p. 977). The same effects are produced on animals. Pereira states that he did not succeed in obtaining the chemical test noted in the text, viz., the green alcoholic solution and the yellow resin on evaporation. Hassall figures the starch grains of the lolium as small and something like rice; fifty or sixty may adhere together and form a compound grain not very unlike the oat. The envelopes are tolerably distinctive; the cells of the outer coat are made up of a single layer, and are disposed transversely instead of longitudinally. The second coat is in two layers, and the cells have a vertical arrangement. The third coat is like the inner coat of wheat. This account is taken from Hassall.

It is not very likely that any other grains except those mentioned in the text will be mixed with wheat flour. The seeds of the Peruvian food, *Chenopodium Quinoa*, have not apparently been used as a falsification. The starch grains of the Quinoa are said to be the smallest known. It may be worth remarking that this seed is very rich in salts (2·4 per cent.), and particularly so in iron (0·75 per cent.); indeed, it is the richest in iron of any vegetable. It is possible that it might be a useful food in some cases of illness. It is fairly nutritious and digestible.

The starch grains of the acorn, which might perhaps be added in times of great scarcity, would be immediately detected, as they have a very characteristic central depression, and are also quite different in shape from the flat, round, smooth starch cells of the wheat and barley.

solution, with an agreeable taste (Pellischek). Sulphuric acid reddens the outer envelope.

Bromus or *Serrafalcus* (Brome-grass—*Gramineæ;* different species—*Arvensis* or *Secalinus*).—Pellischek states that the seeds of this plant give the bread a dark colour, and make it indigestible. It is probably a most uncommon adulteration.

It will be found that, when mixed with flour, the microscope will detect readily many of these substances. Detection is often very difficult when the flour is made into bread, and therefore, whenever, from the bread, there is any cause of suspicion, means should be taken to obtain some of the flour.

Cones Flour.—A flour obtained from Revel wheat is used by bakers for dusting their troughs. Hassall has found this Cones flour to be greatly adulterated with rice, maize, beans, rye, and barley. Sometimes Cones flour is mixed with good flour. Several samples examined at Netley contained nothing but rice. This is sometimes sold as "Rice Cones"; there may be some advantage in the dryness of the rice.

Cooking of Flour.

The effect of heat is to coagulate the albumen and to transform some of the starch into dextrin. Substances are also added to the bread to cause a further transformation of the starch.

Cakes.—The unfermented cakes[1] are simply made with water and salt. As they are very readily made, are agreeable to taste, and nutritious, it is very desirable to teach every soldier to make them, so that in war, when bread is not procurable, he may not be confined altogether to biscuit. The Australian "damper" is simply made by digging a hole in the ground, filling it with a wood fire, and, when the fire has thoroughly burnt up, removing it, placing the dough on a large stone, covering it with a tin plate, and heaping the hot ashes round and over it. In a campaign, every soldier, if he could get flour and wood, would soon learn to bake a cake for himself. The only point of manipulation which requires practice is not to have the heat too great; if it be above 212° too much of the starch is changed into dextrin, and the cake is tough. Exposed to greater heat, and well dried, the unfermented cakes become biscuit.

Macaroni is flour from a hard Italian grain, moistened with water, and pressed through a number of small openings, while at the same time heat is applied. As it is very nutritious in small bulk and keeps well, it would be a good food for soldiers in war if its cost could be lessened.

Sub-Section III.—Biscuit.

To make biscuit, flour is often taken with little or no bran (on account of the hygroscopic properties of bran); but bran is also sometimes used; no salt is added. The simplest biscuits are merely flour and water. Some biscuits are made with milk, eggs, &c.

Choice of Biscuit.—Biscuit should be well baked, but not burnt; of a light yellow colour, and should float and partially dissolve in water; when struck, it should give a ringing sound; and a piece put into the mouth should thoroughly soften down. It should be free from weevils, which are easily seen.

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[1] The Chupatty of India.

Advantages as a Diet.—As it contains little water, and, bulk for bulk, is more nutritious than bread, three-fourths of a pound are usually taken to equal 1 ℔ of bread. Its bulk is small, and it is easily transported.

Disadvantages.—Like flour, it is deficient in fat. After a time it seems difficult of digestion. Perhaps the want of variety is objectionable; but certain it is that men do not thrive well upon it for long periods. In war, it has always been a rule with the best English army surgeons, for more than a century, to issue bread as much as possible, and to use biscuit only in cases where it cannot be avoided.

Sub-Section IV.—Bread.

If carbon dioxide gas is in any way formed in or forced into the interior of dough, so as to divide the dough into a number of little cavities, bread is made.

There are three kinds of bread :—

1. Carbon dioxide is disengaged by a fermentative process, caused by yeast or leaven. During the baking a certain amount of preformed sugar yields CO_2; a portion of starch is converted into dextrin and sugar, and also yields CO_2; a little lactic and butyric acids, and extractive matters are formed. It is of importance to prevent this change from going too far; and herein is one of the arts of the baker; and it is partly to prevent this that alum is added, which has the property of arresting the change.

In making bread, the proportions are 20 ℔ of flour; 8 to 12 ℔ of tepid water; 4 oz. of yeast, to which a little potato is added; and $1\frac{1}{2}$ to 2 oz. of salt. 280 ℔ of flour (1 sack) will give from 90 to 105 4-℔ loaves, or 100 ℔ of flour will make from 129 to 150 ℔ of bread. If there is 14 per cent. of water in the flour, the bread will contain in the former case 33·1 per cent., and in the latter 42·7 per cent. If 100 ℔ of flour contain 14 per cent. of water, and make $141\frac{1}{2}$ ℔ of bread, the bread will contain 40 per cent. of water; the baker always endeavours to combine as much water as he can, so as to get more loaves. $6\frac{1}{2}$ ℔ of dough yield 6 ℔ of bread. Machines are now generally used for mixing the dough (Stevens' Machine).

2. CO_2 is disengaged by mixing sodium or ammonium carbonate with the dough, and adding hydrochloric, tartaric, phosphoric, or citric acids. Baking powders are compounds of these substances.

3. CO_2 is forced through the dough by pressure (Dauglish's patent aërated bread). This process has the great advantage of rendering it impossible that the conversion of starch into dextrin, sugar, and lactic acid shall go too far. About 20 cubic feet of CO_2 (derived from chalk and sulphuric acid) are used for 280 ℔ of flour; and about 11 cubic feet are actually incorporated with the flour (Odling).

Advantages of Bread as an Article of Diet.

It is hardly necessary to mention these. The great amount of nitrogenous matters and starch it shares with flour; the nitrogen is to the carbon as 1 to 21. It therefore requires more nitrogen for a perfect food. The process of baking renders it more digestible than flour. No satiety attends its use, although it may be always made in the same way; this is probably owing to the great variety of its components.

Disadvantages.—It is poor in fat and some salts, especially in the case of the finest flour freed from the internal envelope. Therefore we see that the practice of using fat with it (butter for the rich, fat bacon for the poor

man) is extremely common. As to the relative advantages of the three methods of making bread, the last (aëration by CO_2) is said to have the advantage of making white bread, though the inner envelopes are left; of not causing any loss of starch, or permitting the change to go too far; of not containing any unwholesome yeast. The system of making bread with yeast has been objected to on the ground that bad yeast is often used; the fermentative changes go on in the stomach, much CO_2 is disengaged, and dyspepsia, flatulence, and unpleasant sensations, such as heart-burn, are produced. There is no doubt that badly prepared bread gives rise to these symptoms, though that this is owing to bad yeast is at least uncertain. The second method yields a wholesome bread, but is too expensive for common use, and it has also been pointed out that the hydrochloric acid of commerce always contains arsenic. The amount would be too small to be hurtful, but might be of medico-legal consequence.

Special Points about Making of Bread.

Bread may be of bad colour—rather yellowish, from old flour; from grown flour (in which case the changes in the starch have generally gone on to a considerable extent, and the bread contains more sugar than usual, and does not rise well), and perhaps from bad yeast. The colour given by admixture of bran must not be confounded with yellowness of this kind.

Bread is also dark coloured from admixture of other grains, as already noticed under flour (rye, buckwheat, melampyrum, sainfoin, &c.). Bread may be acid, from bad flour giving rise to an excess of lactic and perhaps acetic acids, or, it is said, from bad yeast. In finding the cause of acidity in bread, look first to the flour, which may be old and a little discoloured, and too acid; if nothing can be made out, examine the yeast, and change the source of supply; then look to the vessels in which the dough is kneaded, and to the water. Enforce great cleanliness on the part of the men who make up the dough. In India bread becomes sour from bad cleaning of the flour. Dr Godwin, M.S.,[1] states that at Bareilly the wheat was imperfectly ground in small hand-mills; it was then separated by sifting into four portions, viz., bran; "attar," which corresponds to pollards; "soojie," which consists of glutin and starch; and "maida," which is nearly all starch. The soojie, from imperfect grinding, is granulated, and chiefly used for bread, a small portion only of maida being mixed with it. To cleanse the wheat before grinding it, it was washed and then dried in heaps in the sun. The heaps of corn were quite hot to the feel. A very acid bread was given, but when the wheat was not thus washed it yielded a good bread.

Bread is heavy and sodden from bad yeast fermenting too rapidly, or when the fermentation has not taken place (cold weather, bad water, or some other cause will sometimes hinder it), or when the wheat is grown; when too little or too much heat has been employed. It is said also that if the flour has been dried at too great a heat (above 200° Fahr.) the glutin is altered and the bread does not rise well. It is bitter from bitter yeast.

It becomes mouldy rapidly when it contains an excess of water.

Rice is used as an addition because it is cheaper; it retains water, and therefore the bread is heavier. Rice bread (if 25 per cent. of rice be added) is heavier, of closer texture, and less filled with cavities. Potatoes are sometimes added, but are generally used only in small quantity with the yeast.

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[1] *Army Medical Reports*, vol. vii. p. 451.

Alum is added to stop an excess of fermentation, when the altering glutin or cerealin acts too much on the starch, and it also whitens the bread; it does not increase the amount of water; it enables bread to be made from flour which otherwise could not be used. Sulphates of copper and of zinc, in very small amount, are sometimes employed for the same purpose.

For acid flour, lime water is used instead of pure water; lime water has this advantage, that, while it does not check the fermentation of yeast, it hinders the action of diastase on starch. It must be caustic lime water, and not chalk and water, as sometimes is the case.

Loaves are generally weighed when hot, and that is considered to be their weight. In the Austrian army, a loss of 2·9 per cent. in four days is permitted.

After being taken from the oven bread begins to lose weight.[1]

The loss of weight depends upon size, amount of crust, temperature, and movement of air.

In a sheltered place, at ordinary temperature, a 2-℔ loaf, baked with crust all over, loses about $\frac{3}{4}$ per cent. in cooling, and from 1 to $1\frac{1}{4}$ in five hours.

A similar loaf, with only top and bottom crust, loses 3 per cent. in cooling, and about 4 per cent. in five or six hours. A loaf with four sides crust loses 2 per cent. in cooling, and retains its weight without much further loss for five hours. For each of six sides that is not crust there is a loss of weight of about 1 per cent. in the first five hours.

At the end of twenty-four hours the proportion is about one half more, and the total loss is doubled at the end of seventy-two hours (three days). If the bread is baked in larger loaves (4 ℔, for instance) the loss will be proportionately less, the ratio of the evaporating surface to the bulk of the loaf being diminished.

When loaves become stale they can be dipped in water and rebaked, and then taste quite fresh for twenty-four hours; after that they rapidly change.

Old biscuit also, soaked in water, can be rebaked, and becomes palatable.

In the French army different kinds of bread are used:[2] ordinary bread, biscuited bread, bread half biscuited, bread one quarter biscuited, hospital bread. The "Pain biscuité" is used only on service; it is baked more firmly than ordinary bread.

Pain de munition ordinaire	keeps	5 days in summer and 8 in winter.
,, au quart biscuité	,,	10 to 15 days.
,, demi ,,	,,	20 to 30 ,,
,, biscuité	,,	40 to 50 ,,

The French munition loaf weighs 1·5 kilogrammes (3·3 ℔ avoir.), and contains two rations of 750 grammes (each 1·65 ℔). The ration of biscuit is 550 grammes (1·2 ℔).

It would be useful to adopt the practice of strongly baked bread in our army; it is a good substitute for biscuit.

For Chemical examination of Flour and Bread, see Book III.

Microscopical Examination of Bread.

This is of very little use, as far as adulteration is concerned, but the presence of *fungi* can be detected.

The most common *fungus* is a kind of *Penicillium* (*sitophilum* and *roseum*), which gives a greenish, brownish, or reddish-yellow colour; sporules, sporangia, and mycelium can all be seen. The *Oïdium aurantiacum* has been

[1] See Report on Hygiene, *Army Medical Reports*, vol. xviii. p. 219.
[2] *Code des Officiers de Santé*, 1863.

several times detected in France and Algeria; it is distinguished by its orange-red colour. A greenish *Mucor* is often found in bread. *Puccinia*, so common in flour, has not been detected.

Diseases connected with the Quality of Flour and Bread.

1. *The Flour originally bad.*—It may be ergoted, or grown and fermenting, or with *fungi* forming. An anomalous disease approaching to ergotism should lead at once to an examination of the flour. The fermenting flour produces dyspepsia and diarrhœa; the heat and moisture of the stomach, no doubt, excite at once very rapid fermentation; the glutin, already metamorphosing, acts very energetically on the starch, and CO_2 is rapidly developed; hence uncomfortable feelings, flatulence, imperfect indigestion, and diarrhœa. It is to remedy this condition of flour that alum is added, and some of the effects ascribed to alum may be really owing to the flour.

The most important disease connected with flour is, however, ergotism; this is less common in wheat than in rye flour, but yet is occasionally seen. Sometimes ergoted meal produces at once violent stomach and intestinal symptoms, at other times primary digestion is well performed, and the early symptoms are great general depression and feverishness, ushering in the local symptoms of acrodynia.

2. *Flour originally good, but altering either from age or from not having been well dried.*—The bread is often acid, and sometimes highly so; this may produce diarrhœa, though such bread has sometimes been used for a long time without this effect; usually persons will not eat much of it, and thus the supply of nutriment is lessened. If the bread be too moist, *fungi* form, and *Oïdium aurantiacum*, in particular, has been known in Algiers to give rise to little endemics of diarrhœa (Boudin and Foster).[1] *Mucor mucedo* either does not produce this, or rarely. It should be remembered, however, that mouldy oats (the *fungus* being *Aspergillus*) have given rise to paralytic symptoms in horses, so that these *fungi* are to be looked on with suspicion;[2] and a case of the kind has been reported by H. Hoffman in Giessen.[3] Professor Varnell also states[4] that six horses died in three days from eating mouldy oats; there was a large amount of matted mycelium, and this, when given to other horses for experiment, killed them in thirty-six hours; there was a "peculiar growth" on the mucous membrane of the small intestine. It is not known that *Acarus*, so common in flour, has any bad effects when eaten.

3. *Substances added.*—*Alum*, of course, is the chief substance; there has been much difference of opinion as to its effects. It has been asserted to produce dyspepsia; to lessen the nutritive value of bread by rendering the phosphoric acid insoluble, and to be also a falsification, inasmuch as it permits an inferior flour to be sold for a good one. The last allegation is no doubt correct; the second probably so, as there is little doubt of the formation, and none of the insolubility, of aluminum phosphate. The first point is more doubtful, though several physicians of great authority (Carpenter, Dundas, Thomson, Gibbon, Normandy) have considered its action very deleterious, and that it causes dyspepsia and constipation. Pereira considered that whatever may have been the effect in the case of healthy persons, sick persons did really suffer in that way. A question like this is obviously difficult of that strict proof we now demand in medicine.

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1 *Archives Gén. de Méd.*, 1848, p. 244.
2 Sanderson's Report in *Syd. Soc. Year-Book for* 1862, p. 462.
3 Virchow's *Archiv*, Band xliii. p. 173. 4 *Journal of the Society of Arts*, April 1865.

Seeing, indeed, that the usual effect of bad flour is flatulence and diarrhœa, if constipation were decidedly produced by bread, it would be more likely to proceed from alum than from any other ingredient of the bread. Looking again to the fact that sometimes bread has contained large quantities of alum,—sometimes as much as 40 grains in a 4-lb loaf, and probably more,—we get an amount in an ordinary meal which (if the aluminum phosphate is an astringent) might very well cause constipation. Looking, then, to the positive evidence, and the reasonableness of that evidence, it seems extremely likely that strongly alumed bread does produce the injurious effects ascribed to it.

The addition of alum is forbidden by law.

Sulphuric acid is said to be added[1] before grinding instead of alum: it has the same power of preventing decay.

Sulphate of Copper.—The amount is so small that it seldom produces any symptoms; still it is possible that some anomalous cases of stomach irritation might be owing to this.

Lead.—Dr Alford,[2] medical officer for Taunton, reports a case of poisoning from lead getting into flour. Six or seven families, including fifteen to twenty persons, suffered, some very severely. The water was analysed, but no lead found, and then it was noted that the persons attacked all got their flour from the same mill. On making inquiries, it was found that the mill-stones used had (from the nature of the stone) large spaces in them, which had been filled up with lead! It was mentioned at the meeting of the sanitary authority, by one of the members, that lead was not usually employed in that way, that what was generally used was red-lead and borax, or alum and borax, both highly objectionable. If such be the case, this is another possible source of alum, which ought to be recollected.

Lolium temulentum gives rise to narcotic symptoms.

Flour from other Grains.—It is not known whether the addition of potatoes, rice, barley, peas, &c., in any way injures health, except as it may affect nutrition or digestion. Occasionally, in times of famine, other substances are mixed—chestnuts, acorns, &c. In 1835, during famine, fatal dysentery appeared in Königsberg owing to the people mixing their flour with the pollen of the male catkin of the hazel bush. In India the use of a vetch, *Lathyrus sativus* (kisārī-dāl), with barley or wheat, gives rise to a special paralysis of the legs when it exceeds one-twelfth part of the flour; *L. cicera* has the same effect.[3] During the siege of Paris, straw, to the extent of one-eighth, was introduced into the bread: this had a very irritating effect.

SECTION III.

BARLEY.

As an article of diet, barley has the same advantages and disadvantages as wheat. It is said to be rather laxative (Pereira), and it was noticed by the late Dr Parkes that, either from this cause or from the imperfect separation of the sharp husks, barley bread was particularly unsuited for dysenteric cases. The barley grain contains about as much protein bodies as wheat,

[1] Dr Angus Smith, *Annual Report of the Manchester and Salford Sanitary Association for* 1863.—*Report of Sub-Committee.*

[2] *Sanitary Record*, May 25, 1877.

[3] Dr Irvine (*Indian Annals*, Jan. 1868) described the symptoms produced by the Kisārī-dāl, or *Lathyrus.* The first symptoms are gastro-intestinal irritation, and the paraplegia follows on this.

and these consist of glutin-casein, glutin-fibrin, mucedin, and albumen.[1] In the table on page 243 an analysis of barley meal is given, showing its richness in nitrogenous principles. The analysis of *pearl barley* is from Professor Church, and shows a much smaller amount, due perhaps to the more complete removal of the outer envelope; but in a sample analysed at Netley as much as 11·37 of albuminoids was found. Barley is certainly very nutritious, and the Greeks trained their athletes on it. Its richness in phosphoric acid and iron render it particularly adapted for this.

Choice of Barley (Scotch or pot barley, viz., the grain without the husks). —For the barley grains the same points are to be attended to as in wheat.

For the pearl barley (which is merely the grain rounded off) the best tests are the physical characters, colour, freedom from dust, grit, and insects, and the test of cooking.

The patent prepared or powdered barley should be examined with the microscope; any kind of cheaper grain may be mixed with it.

Diseases arising from Altered Quality.—These are the same as those of wheat, viz., indigestion, flatulence, and diarrhœa. There appears to be nothing peculiar in the action of diseased barley as distinguished from diseased wheat.

SECTION IV.

OATS.

Oats have been considered even more nutritious than wheat or barley, and, certainly, not only is the amount of nitrogenous substance great, but the proportion of fat is large. Unfortunately the nitrogenous substance has no adhesive property, and bread cannot be made of it; the amount of indigestible cellulose is large. But, on the other hand, oatmeal has the great advantage of being very readily cooked, much more so than wheat or barley. The researches of Kreusler[2] show that the nitrogenous substances of oats contain gliadin, and especially glutin-casein. This last substance is that called "avenin" by Norton and Johnstone; it approaches very closely to the legumin of peas and beans, and is so called by Ritthausen. In nutritive properties it causes oatmeal to stand nearer to the *Leguminosæ* than the cereals do. It contains double as much sulphur as the legumin of peas.

For this reason, and because it contains much nutriment in small bulk, because it can be eaten for long periods with relish, and keeps unchanged for a long time, it would seem to be an excellent food for soldiers during war—an opinion which does not lose in force when we remember that it formed the staple food of one of the most martial races on record, the Scotch Highlanders, whom Jackson considered also one of the most enduring. Formerly, when oats were badly cleaned, intestinal concretions of the husk and hairs were common among those who lived on oatmeal, but these are now uncommon. It has been thought to be "heating" when taken continually, but this is probably a prejudice. The supporting qualities of oatmeal used as a drink, made into a thin gruel, are testified to in hard work by the chief and divisional engineers of the Great Western Railway.[3]

Adulterations.—Barley meal and the husks of barley, of wheat, and of oat itself are added very frequently. A single look through the microscope

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[1] Ritthausen, *op. cit.*, p. 103.
[2] Ritthausen, *op. cit.*, p. 125.
[3] *On the Issue of a Spirit Ration during the Ashantee Campaign of* 1874, Appendix ii., by E. A. Parkes, M.D., F.R.S., &c., 1874.

detects the round and smooth barley starch; the envelopes are recognised with very little more trouble. Rice and maize are also sometimes used. The drawings already given will also enable these substances to be detected. Hassall found about half the samples of oatmeal adulterated.

Choice of Oatmeal.—There should be a good proportion of envelope, but no branny character, which usually arises from barley husks; the starch should not be discoloured. A microscopic examination should always be made, both for adulterations and *Acari.*

SECTION V.

MAIZE AND RYE.

Both these grains are very nutritious; maize contains a large quantity of yellowish fat (6 or 7 per cent.). The glutin cannot be washed out as in wheat, though this was stated by Gorham, who found a special substance which he termed "Zeïn." This is called "maize-fibrin" by Ritthausen. It requires very careful cooking, as otherwise much passes out undigested. Dr Johnstone noticed an outbreak of diarrhœa in a military prison clearly due to badly cooked maize. It should be soaked in water, but not too long (two to four hours), and then thoroughly boiled for several hours (four to six) at a rather low heat. Maize cakes are both palatable and nutritious.

Rye makes a very acid dark bread, which causes diarrhœa in those unaccustomed to it; custom, however, soon remedies this, and, as far as nutritive value goes, it appears equal to wheat. It contains less vegetable fibrin, and more casein and albumen, and a peculiar odorous substance.

Diseases connected with Maize and Rye.

It is presumed that alterations in the flour will produce the same diseases as in the analogous case of wheat. Ergotism is, however, more common in rye than any other grain. The Pellagra of Lombardy has been ascribed to a *fungus* (Verderame, or Verdet) forming in the maize. Many volumes, with different statements, have been written on this point, and it is still doubtful whether or not the Verdet has this effect. The evidence is not sufficient, but, on the whole, seems most in favour of the view which connects Pellagra with diseased maize.

SECTION VI.

RICE.

The whole grain (paddy) deprived of the husk is sold as rice. There are many varieties, of different colours (white, red, brown?) and composition. The amount of nitrogenous matter varies greatly, from 3 to 7·5 per cent. As an article of diet it has the advantage of an extremely digestible starch-grain, and, like the other *Cerealia*, there is a great admixture of substances; it is, however, poorer in nitrogenous substances than wheat, and is much poorer in fat. Consequently, among rice-feeding nations, leguminous seeds are taken to supply the first, and animal or vegetable fats to remedy the latter defect. Rice is also poor in salts.

Cooking of Rice.—It should properly be steamed, not boiled, and the steaming should be thoroughly done, else the starch grains are not swollen

and digestible. If boiled, it should not be for too long a time, otherwise the rice (or conjee) water contains some albuminous matter, and the grain loses in nutritive power.

Choice of Rice.—The grains should be clean, without grit; the individual grains without spots or evidence of insects. The size varies much, according to the kind; the large kinds usually command the highest market price.[1]

SECTION VII.

MILLET, RAGGY, BUCKWHEAT.

Various other grains belonging to the *Cerealia*, or to other natural orders, but having similar properties, are used as food in different countries. Of these, the above-named are chiefly those the medical officer may have to report on.

Millet is used largely in Africa (west coast) and Algeria, in Italy, Spain, Portugal, some parts of India, China, &c.

English Names.	Botanical Names.	Indian Names.
Common millet,	*Panicum miliaceum*,	Sañwā Chhenawārī (Hindustani). Varagū (Tamul).
Small millet,	*Sorghum* or *Panicum vulgare*,	Dharrā (Arabic). Cholam (Tamul). Joār or Joārī (Hind.).
Spiked millet,	*Pencillaria spicata*,	Bājrā or Bājrī (Hind.). Kambū (Tamul).
Golden-coloured millet,	*Sorghum saccharatum*,	
Italian millet,	*Setaria Italica*,	Kālā kangnī (Hind.). Tenay (Tamul).
German millet,	*Setaria Germanica*,	
	Eleusine corocana,	Rāgī or Raggy (Hind., Canarese, and Tamul). Murha and Maud in the N. Prov. of Hindustan.[2]

The millets are very similar in composition (as given in the table, p. 243). The ash is rich in silica and phosphates.

Millet bread is very good, and some was issued to the troops in the last China Expedition. This should always be done in a millet country, if wheat or barley cannot be got. In Northern China millet is almost exclusively used.

Raggy or Rāgī, Murha and Maud of the upper provinces (*Eleusine corocana*), is largely used in Southern India (Mysore) and in some parts of Northern Hindustan, and is considered even more nutritive than wheat. It is indestructible, and can be preserved for many years (even sixty) in dry grain pits.

Buckwheat is not so likely to be used. It is poor in nitrogenous substances (7 to 8 per cent.) and fat, and contains a good deal of indigestible cellulose, but it makes a good-tasting bread.

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[1] The larger grains—especially the American kinds—have often much less flavour than the smaller and less attractive Indian kinds.

[2] The native names of the Indian grains and pulses used, especially in Southern India, are given very fully in a paper by Mr Elliot (*Edinburgh Philosophical Journal*, July 1862); and also in Mr Cornish's excellent paper (*Madras Medical Journal*, February 1864).

SECTION VIII.

LEGUMINOSÆ.

The *Leguminosæ*, in respect of dietetic properties, are broadly distinguished from other vegetables by their very large amount of nitrogenous substance, called legumin or vegetable casein; there are, in addition, a little albumen and other protein bodies. The advantages of peas and beans as articles of diet are the great amount of legumin, and the existence of much sulphur and phosphorus in combination with the legumin; in salts also they are a little richer than the *Cerealia*, especially in potash and lime, but are rather poorer in phosphoric acid and magnesia; 1 ℔ of peas contains about 168 grains of salts. The disadvantage of peas and beans is a certain amount of indigestibility; about 6·5 per cent. of the indigested pea passes out unchanged, and starch-cells, giving a blue reaction with iodine, are found in the fæces; much flatus is also produced by the hydrogen sulphide formed from the legumin. Still, they are a most valuable article of food, and always ought to be used when much exercise is taken, as they are an excellent addition to meat and *Cerealia*. Both men and beasts can be nourished on them alone for some time. Added to rice, they form the staple food of large populations in India. Mr Cornish mentions that, in the Sepoy Corps, the men are much subject to diarrhœa from the too great use of the "dāl" (*Cajanus indicus*). Gram (*Cicer arietinum*), although chiefly used for horses and cattle, is sometimes employed as food for men in India: it makes palatable and nutritious cakes.

Choice of Pea.—By keeping, peas lose their colour, become very pale and much shrivelled, and extremely hard. Anything like decomposition, or existence of insects, is at once detected. The powder does not keep very long; the whole peas should be split. The microscope should be used to detect *Acarus*.

Cooking of Peas and Beans.—They must be boiled slowly, and for a long time, otherwise they are very indigestible. If old, no amount of boiling softens them,—in fact, the longer they are boiled the harder they become; they should then be soaked in cold water for twenty-four hours, crushed, and stewed; in this way even very old peas may be made digestible and palatable. Chalk-water must be avoided in the case of peas as of other vegetables, as the lime-salts form insoluble compounds with the legumin.

Lathyrus sativus (Kisārī-dāl of India).—Occasionally in Europe, and constantly in some parts of India, this vetch has been used when mixed with wheat or barley flour for bread. When used in too great quantities, it produces (without there being necessarily any alteration of the grain?) constipation, colic, and some form of indigestion, and, if eaten in large quantity, paraplegia. It is also injurious to horses, but less so to oxen. In Bengal, Dr Irvine[1] found in some villages no less than from 10 to 15 per cent. of the people paralytic from this cause. From its composition, it would not appear to be innutritious.

[1] *Indian Annals*, 1857. *Ibid.*, Jan. 1868, p. 89, Dr Irvine notices the resemblance of the symptoms to the Barbiers of Bontius.

SECTION IX.

STARCHES[1] AND SUGAR.

Sub-Section I.—Arrowroots.

Maranta Arrowroot (West Indian).—The chief kind is obtained from *Maranta arundinacea.* The quality of *Maranta* arrowroot is judged of by its whiteness; by the grains being aggregated into little lumps, and by the jelly being readily made, and being firm, colourless, transparent, and good tasted. The jelly remains firm for three or four days without turning thin or sour, whereas potato flour jelly in twelve hours may become thin and acescent. Under the microscope the starch grains are easily identified. They are slightly ovoid, like potato starch, but have a mark or line at the larger end (the hilum of the potato starch is at the smaller end); the concentric lines are well marked. The most common adulterations are sago, tapioca, and potato starch. All these starch grains are readily detected by the microscope.

Curcuma Arrowroot.—Arrowroot obtained from *Curcuma* has the same physical characters as *Maranta*, but under the microscope the starch grains are large and oblong, marked with very distinct concentric lines, which, however, are not entire circles, having an indistinct hilum at the smaller end.

Manihot Arrowroot.—This comes from Rio, and is obtained from *Jatropha manihot.* The starch grains are very marked.[1] From this starch tapioca is made.

Tacca or Otaheiti Arrowroot.—Hassall gives a figure which shows that the starch grains resemble those of *Manihot.*

Arum Arrowroot.—The Arum or Portland arrowroot has small, angular, and facetted starch grains, which cannot be confounded with any of the former. They are a little like maize. This is sometimes called Portland Sago.

British or Potato Arrowroot.—Under the term "Farina," potato starch is sold in the market, so white and crackling, and making so good a jelly, that it is not always easy to distinguish it from *Manihot.* The microscope at once detects it. The pear-shaped grains, marked hilum towards the smaller end, and the swelling with weak liquor potassæ, render a mistake impossible. In making the jelly a much larger quantity is required than of Maranta arrowroot. *Maranta arundinacea*, mixed with twice its weight of hydrochloric acid, produces a white opaque paste, whereas potato starch treated similarly produces a transparent acid jelly-like paste.

Canna or Tous-les-Mois *Arrowroot*, obtained from *Canna edulis*, N.O. *Marantaceæ.*—The starch grains are like those of the potato, but much larger, and the concentric lines are beautifully marked and distinct.[1]

Sub-Section II.—Tapioca.

This is obtained from the finest part of the pith of *Jatropha manihot* or *Cassava.*

Under the microscope the starch grains are small, with a central hilum; and sometimes three or four adhere together and form compound grains.

It is adulterated with sago and potato starch, both of which are easily detected by the microscope.

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[1] See table, p. 298-9, and plate of drawings by Dr Maddox further on.

Sub-Section III.—Sago.

The best kinds are derived from the sago palm (*Sagus farinifera*), but the sago of *Cycas circinalis* is also sold; it is, however, inferior.

Granulated sago is either "common" or "pearl"; the latter is chiefly used in hospitals. The starch is soluble in cold as well as in hot water. The starch grains are elongated, rounded at the larger end, and compressed at the other; and hence their shape is quite different from the potato starch. The hilum is a point, or more often a cross, slit, or star, and is seated at the smaller end, whereas in Maranta arrowroot the hilum is at the larger end. Rings are more or less clearly seen.

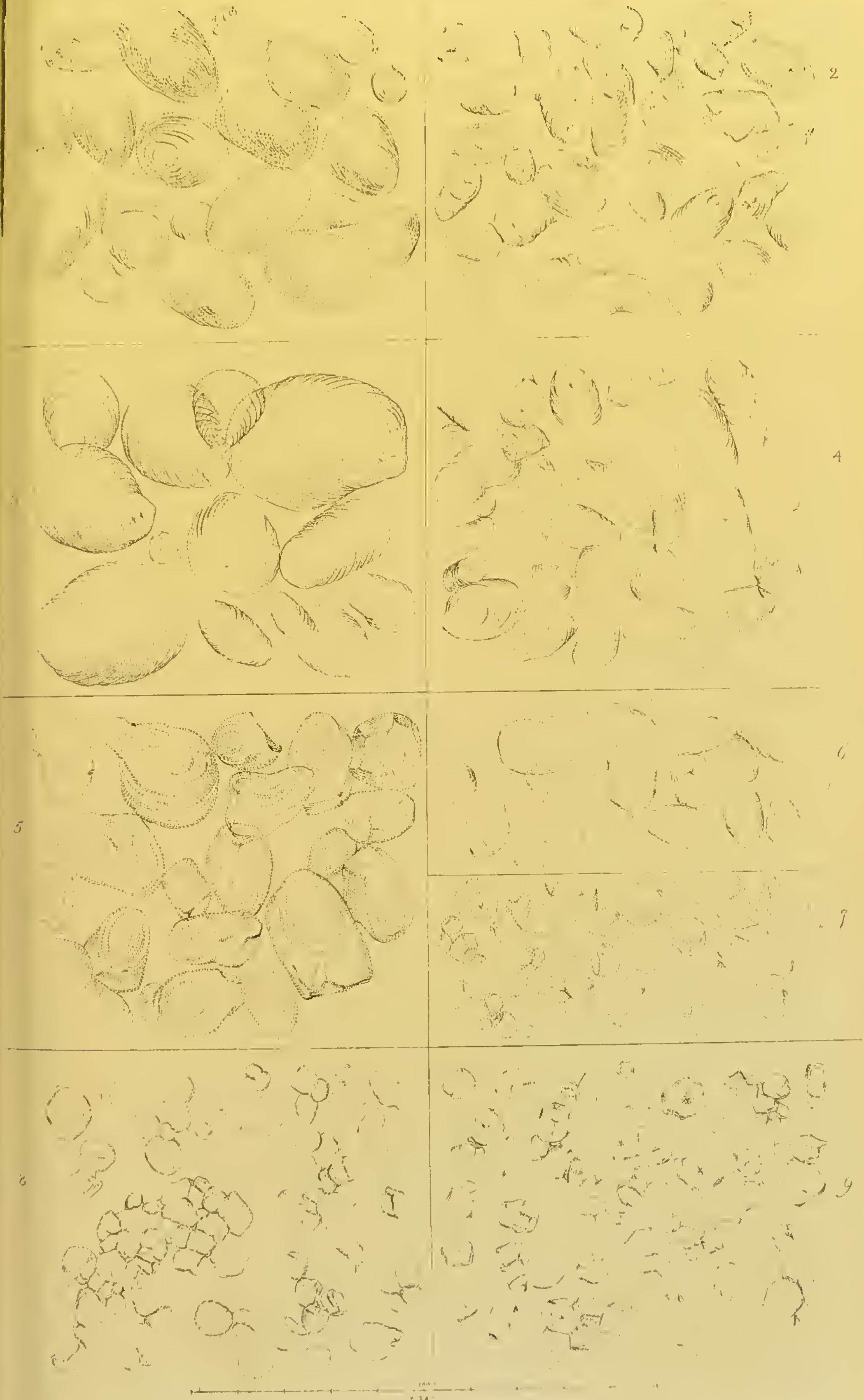
In the market is a factitious sago made of potato flour. This is sometimes coloured red or brownish, either from cochineal or sugar. In thirty specimens Hassall found five to be factitious. The microscope easily detects potato starch.

It is sometimes difficult to remember the characters of the different forms of starch, but it may be to a certain extent facilitated by a tabulated arrangement. The following table has been compiled by Dr J. D. Macdonald, R.N., F.R.S.

Microscopical discrimination of the principal Arrowroots and Starches.

I. *Starches* with isolated smooth or unfacetted grains, being originally free in the cell cavity.

	General Characters.		Particular Characters.		Name.
	Form.	*Hilum.*	*Form.*	*Hilum.*	
Unfacetted.	A.—Contour ovoid. *Hilum* eccentric.	Grains large. *Hilum* at the small end.	Outline even. Continuous rings, oblique, including more than half the grain.	*Hilum* distinct.	Potato; British arrowroot.
			Outline even. Continuous rings, nearly transverse, including less than half the grain.	*Hilum* distinct.	Tous-les-Mois (*Canna*) arrowroot.
				Hilum indistinct.	*Curcuma* arrowroot.
		Grains medium sized. *Hilum* at the larger end.	Outline uneven, often with beak-like projections.	*Hilum* slit-like, triradial or crucial.	Bermuda (*Maranta*) arrowroot.
			Outline more even, beak less frequently seen.	*Hilum* similar, but less apparent.	St Vincent arrowroot.
			Whole grain still smoother and more regular.	*Hilum* similar, but still less marked.	Natal arrowroot.
	B.—Contour oval.	*Hilum* longitudinal, linear lateral.	Grains often broad and reniform.	*Hilum* cleft-like, puckered, irregular.	Bean starch.
			Grains narrower and more uniform.	*Hilum* less puckered and more regular.	Pea starch.
	C.—Contour round.	*Hilum* central.	Form lenticular.	Surface convex at the *hilum*. Grains large and minute only.	Wheat starch.
				Surface depressed at the *hilum*. Grains large, medium-sized, and minute.	Barley starch.
			Form spherical.	*Hilum* often deeply fissured, star-like.	Rye starch.



1 Potato Starch
2 Bermuda Arrowroot
3 Tous les Mois
4 S[t] Vincent Arrowroot
5. Sago of Commerce
6 Port Natal Arrowroot
7 Rio Arrowr[illegible]
8 Tapioca
9. Ma[illegible]

II. *Starches* with the grains facetted by original juxtaposition in the cell cavity. *Hilum* central.

Facetted.	A.—Often presenting the rounded free surface of grains originally superficial in the cluster.	*Hilum* often cavernous.		Grains very large, with a central sinus or cavernous antrum. (Rings sinuous, irregular.)	Sago.
				Grains small. (Sago in miniature.)	Tapioca.
		Hilum stellate.		Grains small. (Like Tapioca without preparation.)	Rio arrowroot.
	B.—Altogether facetted.	*Hilum* stellate.		Grains small. (Discoidal with facetted margin.)	Maize.
		Hilum inconspicuous.	Grains minute.	In rounded glomeruli or compound grains, and free in the cells.	Oats.
				Closely packed in the cells, and fixed.	Rice.

SUB-SECTION IV.—SUGAR.

Choice and Examination.—The sugar should be more or less white, crystalline, not evidently moist to the touch, and should dissolve entirely in water, or leave merely small fragments, which, on examination with the microscope, will be found to be bits of cane. The whiter the quality the less is the percentage of water, which varies in different kinds of sugar, from about 0·25 per cent. (in the finest sugar) to 9 or even 10 per cent. (in the coarser brown sugars). Most of the sugar now sold is very good and pure.

The unpurified sugars contain albuminous matters which decompose, and a sort of fermentation occurs. *Acarus*, or the sugar-mite, is usually found in such sugar, which is not known to be hurtful. *Fungi* also are very frequently present.

SECTION X.

SUCCULENT VEGETABLES.

Almost all other vegetables (except potatoes) are used, not so much on account of nutritive qualities, as for the supply of salts; some of them, however, contain very digestible starch and sugar, or other substances, such as pectin or asparagin, or peculiar oils which act as condiments, as in onions.

SUB-SECTION I.—POTATOES (*SOLANUM TUBEROSUM*).

The potato contains only a small amount of nitrogenous matter and hardly any fat. Its ash is also poor in potash and phosphoric acid. But its starch is very digestible, and it contains a large quantity of vegetable acids and their salts (malates? tartrates? citrates), which form carbonates on incineration. The juice is acid, and there is no better anti-scorbutic. The acids are combined with potash, soda, and lime.

As the amount of salts is small, and that of water large, at least 8 to 12 ounces of potatoes should be taken daily if no other vegetables are eaten (= 8 ounces at 1 per cent. of salts contain 35 grains; at 1·5 per cent. = 52·5 grains).

Choice.—Potatoes should be of good size, firm, cut with some resistance, and present no evidence of disease or *fungi.*

A still better judgment may be formed by taking the specific gravity, and using the following tables :—Multiply the specific gravity by the factor opposite it, and divide by 1000; the result is the percentage of solids :—

Specific gravity, between	Factor.	Specific gravity, between	Factor.
1061–1068	16	1105–1109	24
1069–1074	18	1110–1114	26
1075–1082	20	1115–1119	27
1083–1104	22	1120–1129	28

If the starch alone is to be determined, deduct 7 from the factor, and proceed as before; the result is the percentage of starch.

If the specific gravity of the potato is—

Below	1068	The quality is very bad.
Between	1068–1082	,, inferior.
Between	1082–1105	,, rather poor.
Above	1105	,, good.
Above	1110	,, best.

As, however, the medical officer will seldom have an hydrometer[1] which will give so high a specific gravity, and must work, therefore, with a common urinometer, the following plan must be adopted :—Take a sufficient quantity of water, and dissolve in it ½ an ounce or an ounce of salt, and take the specific gravity; then add another ½ ounce or ounce, and take again the specific gravity; do this two or three times, so as to get the increase of specific gravity for each addition of a known quantity of salt; then add salt enough to bring up the specific gravity to the desired amount. This is, of course, not quite accurate, but in the absence of proper instruments it is the only plan that seems feasible.

Cooking of Potatoes.—The skins should not be taken off, or a large amount of salts passes into the water; using salt water is a good plan, as fewer of the salts then pass out. The boiling must be complete, as the starch-grains are otherwise undigested, and it must be slow, else the cellulose and albuminates are hard. Steaming potatoes is by far the best plan; the heat must be moderate; the steam penetrates everywhere, and there is no loss of salts.

Preservation of Potatoes.—Sugar, in the form of molasses, is the best plan on a large scale; a cask is filled with alternate strata of molasses and peeled and sliced potatoes. On a small scale, boiling the potatoes for a few minutes will keep them for some time. Free exposure to air, turning the potatoes over and at once removing those that are bad, are useful plans.[2]

The preserved potatoes are sliced, dried, and granulated, and when well prepared are extremely useful.

The Sweet Potato and the Yam are somewhat similar to the ordinary potato, and form good substitutes when potatoes cannot be obtained.

Sub-Section II.—Other Vegetables.

The composition of Carrots and Cabbage has been already given. The composition of the other kinds of vegetables is similar.

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[1] Baumé's or Twaddell's hydrometers are the best for the purpose.

[2] In the Crimean war there was a considerable loss of potatoes sent up to Balaclava, and at a time when the men were most in need of them. The addition of sugar to the raw potatoes might have been made.

Some vegetables contain special ingredients, such as asparagin in asparagus (a small amount is also contained in potatoes), wax, pectin, which is a little more oxidised than starch or sugar; or peculiar oils and savoury or odoriferous matters.

On account of its volatile oils, the onion tribe is largely used, and is a capital condiment, and has an effect as an anti-scorbutic. It contains some citrate of calcium.

There are many vegetables which can be employed as anti-scorbutics besides potatoes, onions, and green vegetables. The wild artichokes and *Agave americana* (cactus) are both excellent anti-scorbutics, and the latter is said to be better than lime-juice. Sorrel, and, in a less degree, scurvy-grass and mustard and cress, are useful. In New Mexico a salad made of the "lamb's quarter" (*Chenopodium album*) has been found very useful.[1]

In war almost any kind of vegetables may be used rather than that the troops should be left without such food. In one of the Caffre wars, an African corps kept free from scurvy by using a sort of grass (?) in their soup.

The dried vegetables, and especially the dried potato, have considerable anti-scorbutic powers (Armstrong).[2] The dandelion was largely used in the French army in the Crimean war. The American Indians put up for winter quantities of dried plums, buffalo berries, and choke berries, and thus escape scurvy.[3]

If vegetables cannot be procured, lime-juice ought to be given; or citric acid, or citrate, tartrate, and lactate of potassium. These can be carried as lozenges.

SECTION XI.

COW'S MILK.

A cow gives very variable quantities of milk, according to food and race, and age of the calf; perhaps 20 to 25 pints in twenty-four hours is the average for the year; but with poor feeding it will fall much below this; occasionally a cow, soon after calving, will give 50 pints, but this is not common. A goat will give 6 to 8 pints.

SUB-SECTION I.—MILK AS AN ARTICLE OF DIET.

Milk contains all the four classes of aliment essential to health. Being intended especially for feeding during growth, the proportions of nitrogenous substances and fat, as compared to sugar, are large.

For the average composition of good milk, see table, p. 243.

In addition to casein, a small quantity of true albumen remains in solution after the casein has been thrown down; and there is also, according to

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[1] *Mil., Med., and Surg. Essays prepared for the U. S. Sanitary Com.*, 1864, p. 202. This curious name is said to be given to *Atriplex patula*, on account of its blossoming about the 1st August, from *Lammas quarter* (Palmer's *Folk Etymology*, quoting from Prior).

[2] *Naval Hygiene*, p. 112. In the American war, however, the anti-scorbutic effects of the dried vegetables were not found to be very great. Dr de Chaumont found that, in a sound raw potato, the amount of free and combined acid (reckoned as citric) was 0·5403 per cent.; and that in the preserved potato used in the Arctic Expedition (1875–76) it was 1·085; or in the ratio of 1 to 2·4. From this we find that 7 ounces of the preserved potato contained the equivalent of 31½ grains of citric acid, or one ounce of navy lime-juice. The ration usually issued (2 to 4 ounces) is therefore too small, unless other anti-scorbutics be given. (See *Report of Committee on Scurvy*, Appendix, xiii. 365.)

[3] Hamilton's *Mil. Surg.*, p. 212.

Millon,[1] another albuminoid substance, which he calls lactoprotein. In cow's milk the amount of albumen is said to be 5·25 grammes per litre; the amount of lactoprotein is much smaller, but has not been precisely determined.[2]

The amount of salts varies from 0·5 to 0·8 per cent., but seldom, if ever, exceeds 1 per cent. The usual average is about 0·7 to 0·75. This is of importance in the detection of adulteration by salts. In poor milk the salts may be as low as 0·3 per cent.

Milk is very largely used in some countries, especially in India and Tartary, where the use of the koumiss, prepared from mare's milk, has been supposed to prevent phthisis. This fermented drink is now also prepared from cow's milk, and largely used in this country.

Milk varies in quantity and composition according to—1*st*, the age of the cow; 2*nd*, the number of pregnancies, less milk being given with the first calf (Hassall); 3*rd*, to the age of the calf, being at first largely mixed with colostrum; 4*th*, to the kind of feeding, beet and carrot augmenting the sugar;[3] 5*th*, and remarkably according to the race, some cows giving more fat (as Alderneys), others more casein (as the long-horns). The last portion of the milk given in milking is richest in cream (Hassall).

Wanklyn states that the proportion of solids is more stable, and never falls below 11·5 per cent. In Sweden, the milk of a herd of cows being analysed daily for a year, the solids never fell to 11·5, and only four times to 12 per cent. (Wanklyn).

The goat's milk is rather richer in solids (14·4 per cent.—Payen), and contains also a peculiar smelling acid (hircin or hircic acid). Specific gravity, 1032–1036.

Ass's milk is rather poorer in solids (9·5 per cent.—Payen). This is owing to a small amount of casein and fat; it is rich in lactin. The specific gravity varies from 1023 to 1035.

The buffalo milk is richer in all the ingredients.

Taking the total solids of cow's milk at 13·2 per cent. (specific gravity 1030), one pint (20 ounces) will contain, in round numbers—

Casein,	350 grains,
Fat,	324 ,,
Lactin,	420 ,,
Salts,	61 ,,
Total,	1155 ,,

or more than $2\frac{1}{2}$ ounces avoir. of water-free food.

To give 23 ounces of water-free food (or one day's allowance for an adult), about 9 pints of milk, of specific gravity 1030, are necessary. For an adult this would be far too much water, and the albuminoids and fat would be in great excess. But for the rapid formation and elimination of the young, the water and fat are essential. It is a question whether, in old age, large quantities of milk might not be a remedy for failures in tissue formation and elimination.[4]

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[1] *Comptes Rendus*, t. lix. p. 396.

[2] Commaille (*Comptes Rendus*, Nov. 9, 1868) found creatinin in some putrid milk, derived, he thinks, from creatin. He admits also, after Lefort, that there is a little urea. He found also some organic acids, the nature of which is doubtful.

[3] Some observations of Dr Subbotin (Virchow's *Archiv*, Band xxxvi. p. 561) on the milk of bitches show a marked effect by food: the fat was much increased by meat; the casein was less affected; a large quantity of fat greatly lessened the secretion.

[4] This was a point debated by Galen, so old is this suggestion. It is still undecided. Some old persons cannot digest milk, but this difficulty might be obviated by its being peptonised.

Sub-Section II.—Alterations of Milk.

The cream rises in from four to eight hours; it is hastened by adding warm water, but its quantity is not increased (Hassall). The centrifugal apparatus now in use removes all, or nearly all the cream in a few minutes.

Milk alters on standing; it absorbs oxygen, and gives off CO_2; placed in contact with a volume of air greater than its own bulk, it absorbs all the oxygen in three or four days (Hoppe-Seyler). The CO_2 is formed at the expense of the organic matter (probably casein—Hoppe-Seyler), and bodies richer in carbon and hydrogen are formed; fat increases in amount, and oxalic acid is said to be formed.

Subsequently lactic acid is formed in large quantities from the lactin; the milk becomes turbid, and finally casein is deposited. The cream which had previously risen to the surface disappears.

Milk given by Diseased Cows.

Milk from diseased animals soon decomposes; it may contain colostrum, or heaps of granules collected in roundish masses, pus cells, or epithelium, and occasionally blood. It then soon becomes acid, and the microscope usually detects abnormal cell forms, and casts of the lacteal tubes.

In cattle plague, it is said by Husson that the lactin lessens, while the nitrogenous matters are increased, and blood and aggregated granules are seen under the microscope. In foot-and-mouth disease the specific gravity rapidly falls (from 1030 to 1024), though this is not invariable; there are granular heaps under the microscope, and often blood or pus cells; Mr M'Bride says pus can be found for a month after recovery. *Bacteria* and small oval and round cells are common.[1] The milk sometimes coagulates on boiling.

Sub-Section III.—Preservation of Milk.

1. Boiled, the bottle quite filled, and at once corked up and well sealed, the milk lessens in bulk, and a vacuum is formed above. It will keep for some time. A little sugar aids the preservation. If the heat is carried in a close vessel to 250° Fahr., the milk is preserved for a long time, even for years; the butter may separate, but this is of no consequence.
2. Sulphur dioxide passed through it, or sodium sulphite added. This may be done after boiling.
3. A little sodium carbonate and sugar added, with or without boiling. This will keep for ten days or a fortnight.
4. The addition of salicylic acid, borax, boracic acid, or boroglyceride (Barff's patent).

In the market are—milk in tins, preserved in the usual way by exclusion of air, concentrated milk mixed with sugar, and desiccated or dried milk. This last is milk carefully dried at a low temperature, with a little sugar. Dissolved in water, it forms an excellent milk.

The preserved liquid milk often has the butter separated; if so, it may be spread on bread. It is not easy to remix it with milk, but it is said that the separation may be prevented by adding a little yolk of egg.

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[1] Figures of the microscopical appearances are given in some very good papers on the subject in the *British Medical Journal*, Oct. 1869.

SUB-SECTION IV.—EFFECTS OF BAD MILK.

Professor Mosler[1] has directed attention to the poisonous effects of "blue milk,"[2] that is to say, milk covered with a layer of blue substance, which is in fact a *fungus*, either *Oidium lactis* or *Penicillium*, which seems to have the power, in certain conditions, of causing the appearance in the milk of an aniline-like substance.[3] The existence of this form of *fungus* was noted by Fuchs as long ago as 1861. Milk of this kind gives rise to gastric irritation (first noted by Steinhof); and, in four cases mentioned by Mosler, it produced severe febrile gastritis.

Milk which is not blue, but which contains large quantities of *Oidium*, appears from Hessling's observations[4] to produce many dyspeptic symptoms, and even cholera-like attacks, as well as possibly to give rise to some aphthous affections of the mouth in children.

Milk contaminated with pus from an inflamed udder, or an abscess on the udder, will give rise to stomatitis in children, and to aphthæ on the mucous membrane of the lips and gums.[5]

There has been much discussion whether the milk from foot-and-mouth disease in cows (*Eczema epizootica*) can cause affections of the mouth, or give rise in human beings to any disease similar to that of cattle. Pigs can certainly get the disease from the milk of the cow; sheep and hares, which also have the disease, perhaps get it from the saliva on herbage. In men the evidence is discordant, and in a great measure negative;[6] still there are some striking cases, which seem sufficient to prove that disease of the mouth (aphthous ulceration, general redness, diphtheritic-like coating, swollen tongue), and sometimes, though rarely, an affection of the feet may occur.[7] Some positive evidence has been adduced by Professor M'Bride,[8] Gooding,[9] Hislop,[10] Latham,[11] and Briscoe.[12] It is, of course, possible that some pus or blood from abscesses on the teat or udder may have got into the milk, but it is unlikely that this should have been overlooked.

A remarkable outbreak, which took place in Aberdeen in April 1881, has been recorded by Dr Beveridge. The symptoms were febrile, but anomalous, and their cause is as yet unexplained. The cases were limited to the area of a particular milk supply, 88 per cent. of the families using the milk being attacked.[13] There seems reason to believe that bovine tuberculosis may be communicated to man through milk.[14]

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[1] Virchow's *Archiv*, Band xliii. p. 161 (1868).

[2] Blue milk is given by feeding cows with some vegetable substances, as *Myosotis palustris. Polygonum aviculare* and *fagopyrum, Mercurialis perennis*, and other plants (Mosler); but this is different from the blue colour referred to above.

[3] Erdmann (*Journal für Prakt. Chem.*, xcix. p. 385, quoted by Mosler) has discovered that *vibriones* have the power of producing aniline colouring matter from protein substances.

[4] Virchow's *Archiv*, Band xxxv. p. 561. See also Report on Hygiene, *Army Medical Report*, vol. vi. p. 385.

[5] See a good case by Dr Fagan (*British Med. Journal*, Nov. 13, 1869).

[6] See Dr Thorne's paper in the *Report of the Medical Officer to the Privy Council*, p. 294, and Mr Simon's remarks on it, p. 62. Also Report on Hygiene, *Army Med. Blue Book*, vol. x. p. 223. Dr Lawson Tait's negative evidence against it is exceedingly strong (*Medical Times and Gazette*, October 1869); the disease was all round, and the milk was used, yet not a case occurred which could be referred to it. See also Whitmore's evidence in Marylebone (*British Medical Journal*, Oct. 1869).

[7] A case of the foot being involved is recorded by Mr Amyot (*Med. Times and Gazette*, Nov. 4, 1871).

[8] *Brit. Med. Journal*, Nov. 13, 1869. An anonymous writer in the same *Journal*, Sept. 1869, adduces also a few doubtful cases (p. 327), though his evidence is otherwise negative.

[9] *Medical Times and Gazette*, Jan. 1872.

[10] *Edin. Med. Journal*, Nov. 1868.

[11] *British Medical Journal*, May 1872.

[12] *Ibid.*, Oct. 1872.

[13] *Sanitary Record*, vol. ii. new series, p. 425.

[14] *On Bovine Tuberculosis in Man*, Creighton.

A peculiar disease has several times prevailed in the Western States of America, which is caused by the unboiled (not by the boiled) milk of cows affected with the "trembles," which is supposed to be produced by the cows feeding on *Rhus Toxicodendron.* In children who get this milk-sickness, there is extreme weakness, vomiting, fall in bodily temperature, swollen and dry tongue, and constipation. Boiling appears to remove the hurtful qualities of the milk.[1] Cases of severe diarrhœa have occurred from the use of milk from goats that had fed on *Euphorbium;* this has been observed at Malta.

Milk may also be a means of conveying the poisons of enteric fever, of scarlet fever, and of diphtheria. In the first, it has probably usually arisen from the watering of the milk with foul water containing the agent,[2] but it may possibly have in some cases arisen from the typhoid effluvia being absorbed by the milk, as in the case at Leeds. The scarlet fever and diphtheria poisons have probably got into the milk from the cuticle or throat discharges of persons affected with those diseases, who were employed in the dairy while ill or convalescent. But the recent investigations by Power and Klein seem to show pretty conclusively that cows may either be infected with scarlatina poison from man, or are liable to a disease which, although comparatively mild as regards the animal itself, is capable of communicating scarlatina to man. Klein, by means of careful cultivations, has shown that the *micrococci* found in such milk are identical with those found in scarlatina, and that they are also capable of exciting the disease in animals.[3] There seem also grounds for believing that milk may be the means of transmitting diphtheria from diseased cows, apart from direct contamination from human beings. Mr Ernest Hart,[4] in 1881, collected and tabulated 50 epidemics of enteric fever, 15 of scarlet fever, and 7 of diphtheria, which were traced to milk poisoning, and since that time many others have occurred.

A new poison, a ptomaine, has been discovered by Professor Vaughan of the University of Michigan, U.S.[5] As it was originally found in cheese, he gave it the name of Tyrotoxicon, or cheese-poison. He has since found it in milk that had been kept a considerable time (three or more months). It would thus appear that some time is necessary before its development, but it has been found in marked quantity in ice cream, and is probably the cause of many of the cases of poisoning by that article which are on record.

SECTION XII.

BUTTER.

As an article of diet, butter supplies to most people the largest amount of fat which they take. Many persons take from $1\frac{1}{2}$ to 2 oz. daily, if the butter used in cooking be included, and the average amount for persons in easy circumstances is 1 oz. daily. Butter appears to be easily digested by most persons, except when it is becoming rancid. It then causes dyspepsia and diarrhœa, and as a rule it may be said that decomposing fats of all kinds disagree.

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[1] *Boston Med. and Surg. Journal*, January 1868, and *Transactions of the Kentucky State Medicine Society*, quoted in *Medical Times and Gazette.* There have been many instances in the last half century, and they have all been collected by Hirsch.

[2] See *Report by Mr W. Harvey to the Local Government Board on Fever at Swanage in* 1886.

[3] Lecture to the Royal Institution, by E. Klein, F.R.S., May 1887; also *Proc. Roy. Soc.*

[4] *Transactions of the International Medical Congress*, vol. iv. p. 391.

[5] *Report of Michigan State Board of Health;* see also *Analyst*, Nov. and Dec. 1886.

Composition and Examination.

1. *Water.*—The average amount of water varies from 5 to 10 per cent., but may be higher, even in genuine butter. Hassall has found as much as $15\frac{1}{2}$ per cent. in fresh, and $28\frac{1}{2}$ per cent. in salt butter; Wanklyn records 23·6 per cent. in fresh butter supplied to Paddington Workhouse. The retail dealer, by beating up the butter in water, endeavours to increase the amount. This can be detected by evaporation in a water bath; if the quantity of water be very large, melting the butter will show a little water below the oil. An unusually small amount of water is suspicious (Angell), as suggestive of the presence of foreign fat.

2. *Casein.*—All butter contains some casein, as some milk is taken up with the cream. The best butter contains least. The amount can be told roughly by melting in a test tube. The casein collecting in the bottom does not exceed one-third of the height of the contents of the tube in the best butter, or between one-third and one-half in fair butter. In bad butter it may reach to more than this. A better plan is dissolving the fat by ether, washing and then weighing the remainder; the casein then weighs from 5 to 3 grains in every 100 of very good butter. In bad butter it is much more than this.

The rancidity of butter is chiefly owing to changes in the fat, produced apparently by alterations in the casein, and therefore the greater amount of casein the more the chance of rancidity.

3. *Fat.*—The fat amounts to from 86 to 92 per cent. of the butter. Butter oil consists of volatile fatty acids (butyric, caproic, caprylic, and capric) and of non-volatile acids (stearic, palmitic, and oleic), all combined with glycerin. In examining it, the butter should be melted in a beaker-glass placed in hot water, and the fat should be poured off the casein, and allowed to cool. It then forms a solid and usually yellow mass, with the characteristic smell of butter, and should be futher examined as follows:—

(*a*) *Smell, taste, and colour of this recongealed fat.*—The smell and taste are very characteristic, and with a little care the quality of butter, and even the presence of some adulterations, such as mutton fat, can be determined. The colour is usually yellowish white; other fats are white, but annatto may be used for colouring them, or true butter may be white, so that the coloration is not a safe test.

(*b*) *Examine the recongealed fat with the microscope.*—Butter shows nothing but oil globules; lard and other fats often, but not always, contain acicular and stellate crystals of margaric (really a mixture of palmitic and oleic) and stearic acids, as pointed out by Hassall. Starch and other impurities may be sometimes seen, and tinged by iodine. The casein left after the fat has been poured off should be also examined, and starch, membrane, or other impurities may be seen in it. The polariscope may be used to bring out more strongly the stellate stearic acid crystals, if present. Angell and Hehner point out that even genuine butter sometimes shows crystals after melting and recongealing; they therefore think the presence of crystals ground for apprehension only, showing no more than that the fat has been melted.

(*c*) *Determine the melting-point of the fat after separation from the casein.*—Some of the fat should be put into a wide tube, and placed in an evaporating dish with water; a thermometer should be in the water and another in the fat. Raise the temperature of the water very gradually; remove the lamp from time to time, so that the temperature of the fat may rise slowly. Note the temperature when it begins to melt; when it is completely melted; and when (after removal from the warm water) it begins to recon-

geal, and beeomes quite solid. The melting-points are, however, not eonstant, owing to the variable amounts of stearin and olein and the volatile fatty aeids, but still they run within tolerably narrow limits.

The temperature when the fat is eompletely melted appeared to be the most marked point in Dr Parkes' experiments. The butter oil is most easily melted, and requires the greatest amount of eooling before recongealing; usually there is a differenee, often 12° to 15°, between the points of commeneing and eompleted fusion. The determination of the melting-point is, however, eertainly more useful in proving that the butter has only slight admixture, than in proving eomplete purity, *i.e.*, the presenee of a small quantity of lard or beef dripping would not raise the melting-point sufficiently for deteetion. In the ease of beef dripping, also, the melting-point is rather elose to that of butter.

Temperature[1] *of Melting and Solidifying* (*Degrees Fahr.*).

	Fusion.		Solidification.	
	Commencing.	Completed.	Commencing.	Completed.
	Degrees.	Degrees.	Degrees.	Degrees.
Butter oil, . . .	65–68	80–90	70–80	60–82[2]
Lard, ...	76–80	100–115	90–100	71–75
Beef dripping, . . .	68–85	100–120	90-100	72–76
Mutton dripping, . .	86–100	140–150	120–130	86–92
Palm oil,[3] . . .	81–92	110	88	69

(*d*) Angell and Hehner[4] reeommend examining the sinking-point, by means of a little glass bulb weighted with mereury to 3·4 grammes; the mean sinking-point of 24 genuine butters was 35°·5 C. (96° Fahr.), ranging from 34°·3 C. to 36°·3 C. (93°·7 Fahr. to 97°·3 Fahr.). The butter is melted and poured into a test-tube, and allowed to eool; as it eools a slight eonieal depression appears on the surfaee; this must be rendered even by remelting the upper part. If other fats are present, the depression is mueh more marked. The tube, with the bulb on the top of the fat, is then plunged into a larger beaker of water, whieh is gradually heated until the bulb sinks, the temperature of sinking being noted by means of a thermometer plaeed in the water.[5]

(*e*) Another method, reeommended by the same ehemists, eonsists in determining the pereentage of fixed fatty aeids, whieh seems to be pretty eonstant in butter fat, forming about 87·3 per cent. of its weight; 88·5 being adopted as a maximum, whereas most other fats give about 95·5 per eent.,—the differenee in butter being made up by volatile fatty aeids. The plan employed is to saponify the fat by boiling with eaustic potash and water, to deeompose the soap with hydroehlorie acid, filter and wash with boiling water, and then weigh the fatty aeids remaining undissolved on the filter. The saponifieation

[1] Dr Parkes attached more importance to the melting-point than to the solution in ether.

[2] It is rare for butter oil to be completely solid at 82°, but Dr Parkes once found it so in an undoubtedly pure butter, made during the winter on a gentleman's private farm. But usually butter is not solid till 68° or 65°.

[3] Dr Campbell Brown, of Liverpool.

[4] *Butter: its Analysis and Adulterations*, 2nd ed., 1877.

[5] Hassall employs a converse plan, using a float instead of a sinker, the temperature at which it rises to the surface being noted; this generally oecurs about 2° C., or 5°·6 Fahr. lower than the sinking-point above mentioned. Other plans have been proposed by Dr Tripe, Mr Heisch, Dr Redwood, and Mr Bell. Mr P. Duffy has pointed out the curious fact that pork, mutton, and beef fats have two or three allotropic conditions, with different melting-points.

is much facilitated by commencing the process with methylated spirit, as suggested by Mr G. Turner.

(*f*) The specific gravity of butter fats has also been suggested by Mr Bell as a good means of determining purity. He melts the fat at 100° Fahr., and weighs in a specific gravity bottle. He shows that the specific gravity of ordinary fats varies between 902·83 and 904·56, whilst that of butter fat rarely falls below 910, generally ranging between 911 and 913.[1]

4. Salt is added to all butter. In fresh butter it should not be more than 0·5 to 2 per cent. (8 grains per ounce); in salt butter, not more than 8 per cent. (35 grains per ounce). To determine the salt, wash a weighed portion of butter thoroughly with cold distilled water, and determine the chloride of sodium by standard nitrate of silver. Dr Tidy recommends incineration and weighing the residue; he places the limit at 7 per cent.

By this method the amount of water, casein, oil, and salt will be determined, and the quality of the butter oil will have been examined.

Scheme for a Short Examination.

1. Determine quality by the taste and smell of the whole butter, and of the melted, poured off, and recongealed fat.[2]
2. When melting for the fat in a tube, notice approximate amount of casein.
3. Determine the sinking-point by Angell's plan, or the floating-point by Hassall's.
4. Examine butter and recongealed fat with microscope, and add a weak solution of iodine to test for starch.
5. If time and means allow, determine the percentage of fixed fatty acids in the butter fat, by Angell and Hehner's method, or
6. Determine the specific gravity by Bell's method.

Adulterations.

Butter is supposed to be frequently adulterated with lard, and with beef, mutton, and horse fat, and with vegetable oils. In a process devised by Mége-Mouriès,[3] fresh beef suet is converted into a kind of butter (oleo-margarine). But the original process was so complicated that it would not pay a dishonest tradesman to do it, and it could only be practised on a large scale.

A similar substance from New York has made its appearance of late years in the market under the name of Butterine. Oleo-margarine is now generally defined as a preparation of animal fats, whereas butterine is animal fat beaten up with milk. Large quantities are manufactured in Holland and other countries and sent over to this country. It appears to be a wholesome fat, and as long as it is sold honestly as a substitute for butter, but not as genuine butter, its introduction will probably be a boon to many on account of its cheapness. The sinking-point and the determination of the amount of fixed fatty acids would probably detect it when sold for genuine butter. The Act of 1887 has now decided that the name *Butterine* shall be no longer used, and that artificial butter shall be known as *Margarine.*

Butter is sometimes adulterated by beating up with water: this is frequent in the tropics. It is also sometimes mixed with milk (Angell and Hehner).

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[1] *Pharmaceutical Journal*, July 22. 1876.

[2] Butter becomes rank and bad by the cream being allowed to become sour before churning, in consequence of dirty vessels; it is a good plan to stir up the cream from time to time.

[3] *Pharmaceutical Journal*, Oct. 1872.

Potato or other starches are sometimes added. It is a rare adulteration, and is at once detected by iodine, either at once or after melting. Gypsum and sulphate of barium have been added, it is said; this must be very rare, and be at once detected by melting and pouring everything off the insoluble powder, or by incinerating. Annatto is frequently used to colour butter.

Preservation of Butter.—Pouring water which has been boiled over butter will keep it for some time; but a better plan is one discovered by M. Bréon,[1] viz., water acidulated slightly (3 grammes to 1 litre) with acetic or tartaric acid, is added, and the whole is placed in a close-fitting vessel. Sugar also has a preservative effect, especially when mixed with a little salt. Borax, boric acid, or any of the preparations containing these substances, may also be employed.

SECTION XIII.

CHEESE.

As an Article of Diet.—It contains a very large amount of nitrogenous matter in small bulk (p. 243), and as it is agreeable to the palate, it must be an excellent food for soldiers in war. About $\frac{1}{2}$ ℔ contains as much nitrogenous substance as 1 ℔ of meat and $\frac{1}{3}$ of a ℔ as much fat. It does not, however, keep well in warm climates.

The quality is known by the taste. The only adulteration is from substances to give weight. Starch is chiefly employed, and can be detected at once by iodine. There is usually about 5 or 6 per cent. of salt.

Sulphate of copper and arsenious acid are sometimes used to destroy insects; the rind is then the most poisonous part. Copper is detected by ammonia or potassium ferrocyanide. Arsenic by any test (Reinsch's or Marsh's). Sometimes cheese becomes sour, particularly if made from sheep's milk, and may cause diarrhœa. The occasional production of the ptomaine tyrotoxicon should be remembered when poisonous symptoms arise.

Acarus domesticus, *Aspergillus glaucus* (blue and green mould), and *Sporendonema casei* (red mould) form during decay. During decay the fat augments at the expense of the casein; leucin is produced, and valerianic and butyric acids. Lactic acid is also often produced, from the lactin of the milk contained in the cheese. The aroma of cheese partly arises from this decomposition, and the production of volatile acids.

SECTION XIV.

EGGS.

Composition and Choice.—An egg weighs from 600 to 950 grains, or even more;[2] the average weight is about 2 ounces avoir.; 10 parts are shell 60 white, and 30 yolk; the white contains 86 per cent. of water; the yolk 52 per cent.; 100 grains of egg, therefore, contain—

10	grains	shell.
22·8	,,	albumen and fat.
67·2	,,	water.
100·0		

[1] Payen, *Des Subst. Alim.*, 4th ed., p. 179.

[2] Dr de Chaumont weighed the egg of a Brahma fowl which weighed 1555 grains, of which 112 were shell, or 7·2 per cent., a diminished ratio which would naturally follow from the increase of bulk.

If an egg weighs 2 ounces, it contains nearly 200 grains of solids; this is a convenient number to remember, as 100 grains correspond to 1 ounce.

For choice, look through the egg; fresh eggs are more transparent in the centre, old ones at the top. Dissolve 1 ounce of salt in 10 ounces of water: good eggs sink; indifferent swim. Bad eggs will float even in pure water.

Preservation.—Eggs are packed in sawdust or salt, or are covered with gum, butter, or oil, or placed in lime-water, with a little cream of tartar.[1] Boiling for half a minute also keeps them for some time; in fact, anything which excludes air.

The lime-water gives them, it is said, a peculiar taste, and makes the albumen more fluid.

SECTION XV.

CONCENTRATED AND PRESERVED FOOD.[2]

For the military surgeon this subject is so important, that it is desirable to put the chief facts under a separate section.

It is obvious how important it must be in time of war to have a food which may be at once nutritious, portable, easily cooked, and not liable to deterioration. Lind's sagacious mind long ago saw this, and he strongly urged the advisability of having on board ship prepared food of this kind. It must be remembered, however, that a man must get his 260 to 300, or even 350 grains of nitrogen, and 8 to 12 ounces of carbon, in each twenty-four hours, besides some hydrogen and salts. The work of the body when in activity cannot be carried on with less; and at present these elements cannot be presented to us in a digestible form in a smaller bulk than 22 or 23 water-free ounces. Concentration at present cannot be carried beyond this, and practically has not really been carried to this point. Life, however, and vigour may for some days be preserved with a much less amount; and the total amount of food has been reduced to 11 water-free ounces daily, with full retention of strength for seven days, though the body was constantly losing weight. For expeditions of three or four days, if transport were a matter of great difficulty, soldiers might be kept on 10 or 12 ounces of water-free food daily, provided they had been fully fed beforehand, and subsequently had time and food to make up the tissues of their own bodies, which would be expended in the time, and would not have been replaced by the insufficient food.

When we inquire into the concentrated foods now in the market, some of which profess to supply all the substances necessary for nutrition, we find many of them not very satisfactory. They are often not so concentrated as they might be, or are deficient in important principles, or are disagreeable to the taste.

Dried Meat.—Meat dried at a very low heat. It has lost the greater part of its water, is hard, and requires very careful cooking, but is believed to be nutritious when well prepared.

Messrs M'Call of London have prepared an excellent dry meat; it is sold

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[1] It is said that covering them with a solution of bees-wax in warm olive oil ($\frac{1}{3}$ of bees-wax, $\frac{2}{3}$ of olive oil) will keep them for two years.—*Chemical News*, August 1865, p. 84.

[2] Dr Letheby stated that from 1800 to 1855 there were 177 patents taken out for drying and preserving food. Of these 26 were for drying the food, 31 for excluding atmospheric air, and 8 for giving an impervious coating. The number has since vastly increased, especially in recent years.

in packets, each of which weighs 4 oz., and is intended for one meal. It contains salt and pepper, and 12 per cent. of water.

Hassall's Flour of Meat.—Good fresh meat, freed from visible fat, is carefully dried at a very low temperature, and is pulverised by machinery, so that a very fine smooth powder is formed. This is mixed with about 8 per cent. of arrowroot, 2½ per cent. of sugar, and 3 per cent. of a mixture of salts, pepper, spices, and colouring matter. The object of the arrowroot is to assist its suspension in water. When to this substance bread and a fair amount of fatty and vegetable foods is added, it seems to answer well. It keeps very well; but if the open tins are exposed to the air, after several months it slightly changes colour, and then acquires a peculiar odour. Subsequently it decomposes. But if well fastened, it will keep for a very long time. Dr C. A. Meinert[1] has also brought out a flour or powder of meat (Fleischpulver), which is nutritious and digestible. It contains 68 per cent. of albuminoids, of which 66 per cent. is digestible, including extractives.

Under the terms *Tasajos* and *Charqui*, two kinds of meat are prepared in South America; it is probable that these terms have not always been used in the same sense. According to Mr Bridges Adams, Tasajos is meat cut in thin slices, dipped in brine, and then partially dried. Charqui is thin strips of muscular fibre from which the fat is removed, dried rapidly by sun heat, and sprinkled with maize.

The dried meat of the Kaffirs (beltong) is very much the same; great hunks of beef are sun-dried, and remain undecomposed for a long time. So also in Egypt the meat is dried by exposure to the sun and north wind.

The Pemmican of the Arctic voyagers is a mixture of the best beef and fat dried together, and is an excellent food, though rather expensive. Sugar is sometimes added, and sometimes raisins and currants; the latter would be a very desirable addition where there was a deficiency of vegetable food.

Liebig's *Extractum Carnis* is the juice of meat extracted on the following plan:—Every particle of meat is separated from fat and tendons, and is then subjected for some time to a moderate heat; a viscid dark extract at last collects, which contains the salts, creatin, and other organic nitrogenous substances. Mixed with warm water, this extract gives a highly agreeable and nutritious beef-tea or mutton broth. One ℔ of mutton gives about two-fifths of an ounce of extract. It has the remarkable quality of not decomposing; Liebig had some for fifteen years in a bottle loosely stoppered. On the other hand, the most of the more fluid or jelly-like preparations are apt to decompose or become mouldy early, so that a tin once opened ought to be consumed at once.

There are now numerous samples of *Extractum Carnis* in the market, prepared in South America and Australia. The majority have an almost identical composition.

When Liebig's extract is taken during fatigue, it is found to be remarkably restorative, increasing the power of the heart, and removing the sense of fatigue following great exertion. Mixed with wine, it has been employed with great success in rousing men in collapse from wounds. As, however, most of the nitrogenous compounds in the *Extractum* are not in the form of albumen or fibrin, but of other compounds (creatin, extractives soluble in water and alcohol), it has been supposed that the nitrogen is not capable of being employed in the nutrition of muscles or gland-cells, and, in fact, that

[1] *Armee- und Volks-Ernährung*, von Dr C. A. Meinert, Berlin, 1880. This work contains a great amount of information on the subject of food, as well as extensive tables of analyses. See also *Massen-Ernährung*, 1885, by the same author.

the *Extractum Carnis* does not represent a true nutritive albuminoid.[1] Liebig considered it to be a condiment which increases the power of the stomach to digest vegetable food; and Hörschelmann,[2] who does not consider it a substitute for meat, yet thinks that it aids in digesting hard meat, and that the meat ration can be lessened when it is used. By some its action has been compared to that of tea and coffee, but there does not appear to be any close parallel.

When taken in very large doses, the extract (like large quantities of meat) does sometimes cause heaviness and torpor, and this has been ascribed to the potash salts, but it may be a question whether it is not owing to the excess of the nitrogenous extractive matter.

About 230 grains of extract in one pint of water are nearly equal to a pint of beef-tea made from $\frac{7}{10}$ths ℔ of fresh beef; $\frac{3}{4}$ths ounce of extract in one pint are equal to a pint made from 1 ℔ of fresh beef. There is, however, a general opinion that the extract beef-tea is not so good as that made at once from fresh beef; a mixture of the two is well spoken of.

The "concentrated beef-tea" is beef-tea and the juices of the compressed beef mixed and evaporated. This is a highly nutritious substance, and most useful to the army surgeon. Mixed with wine, and given as soon as possible after wounds are received, in the time of shock and collapse, it was found in the Austrian army (in 1859) to save the lives of many wounded men, and the experience of the Federal American army was to the same effect (Hammond). *Extractum Carnis* is now made also by pressure without heat.

Kemmerich's Concentrated Beef-Tea seems a good form; it contains about 13 per cent. of nitrogenous matter. The extract of beef by the same maker is also useful; it contains 22 per cent. of albumen and peptones, and about 39 of extractives.

Johnston's Fluid Beef contains a large proportion of the fibrin of meat, in addition to the juices. It appears to be a good preparation; according to Stützer, it contains 35 per cent. of albumen and peptones, and about 9 of extract.

Extract of Mutton.—An Australian extract of mutton is now sold, which is more solid than Liebig's extract, and differs from it in containing much fat. It is a very good preparation.

Carnrick's Beef Peptonoids are a mixture of meat, wheat glutin, and evaporated milk, reduced to a powder. They contain between 50 and 60 per cent. of digestible albuminoids and peptones (Stützer). It is claimed that 4 oz. of this powder contains the nutriment of 10 ℔ of Liebig's extract: this is absurd.

Brand's Essence of Beef contains 8 per cent. digestible albuminoids and peptones and about 1 per cent. of extract.

Benger's Peptone Jelly has a similar composition.

Valentine's Meat-Juice has a large quantity of extractive—about 9 per cent.

Savory & Moore's Fluid Meat contains 8 per cent. of albuminoids and peptones and 47 of extractives.

Murdoch's Liquid Food is very nutritious, containing 13 per cent. of albuminoids and 1·2 extractives.

There are various others in the market; among them are some from Russia, which seem very good.

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[1] According to Stützer's analysis (*Analyst*, 1885), Liebig's extract contains 5·3 per cent. of digestible albumen, 1·5 of peptones, and 4·9 extractives of meat. There is thus about a third to a half of the nutritive matter of ordinary meat, weight for weight.

[2] Schmidt's *Jahrb.*, Jan. 1872, p. 21.

Mason & Co.'s preparations, beef-tea, extract and meat lozenges, are also good; the last contain 71·75 per cent. of albuminoids, of which only 3·7 is indigestible.

Kochs' Meat Peptones, in the form of *extract of meat*, and also of *tablets* and *lozenges*, are very good. The extract (a jelly-like mass) contains about 53 per cent. of nitrogenous matter, of which about 28 is peptones and 24 meat-juice extract. The tablets and lozenges are similar in composition, but are more concentrated.

Bellat's Extract of Meat.[1]—This contains the juice of cooked vegetables in addition to that of meat. A little less than an ounce (25 grammes) in $1\frac{3}{4}$ pint (1 litre) of water makes good beef-tea.

Edward's Patent Desiccated Soup consists of a mixture of beef and vegetables; is easily prepared by boiling in water, about an ounce to a pint of water; it was well spoken of in the Ashantee war.

Meat Biscuits.—These biscuits or powders, for they are generally powdered and sold in canisters, are formed by mixing rich extract of meat with wheat flour, and drying. They were very much used in the American war. In some cases the meat is so much dried as to be quite indigestible.

Meat biscuits can be made in a very simple way, by mixing together, cooking, and baking 1 ℔ flour, 1 ℔ meat, 1 ℔ fat (suet), $\frac{1}{2}$ ℔ potatoes, with a little sugar, onion, salt, pepper, and spices. A palatable meat biscuit, weighing about $1\frac{3}{4}$ ℔, containing 10 to 12 per cent. of water, is thus obtained, which keeps quite unchanged for four months.

Pea Sausage.—In the Franco-German war the Germans made great use of a pea sausage (Erbswurst), made by mixing pea-flour and fat pork, with a little salt. It is ready cooked, but it can be made into a soup. It was much relished for a few days, but the men got eventually tired of it, and in some it produced flatulence and diarrhœa. The original erbswurst contained about 16 per cent. of albuminoids, about 35 of fat, and about 27 of starch, &c. Other forms vary in composition. The latest German samples contain 15·7 per cent. total albuminoids, of which 3·5 is indigestible, and about 23 of fat. English samples contain a larger percentage of both albuminoids and fat.

Flour Sausages.—A mixture of pork and wheat flour has been used in the same way.

Maize and Beef.—The Germans in 1870 made use also of a mixture of maize and beef, which appears to have been much liked.

Dried Cerealia.—Many flours, if well dried, will keep for a long time. There are now in the market different kinds of malt biscuit and granulated malt food. Liebig's food for infants is composed of equal parts of wheaten flour and malt flour mixed with a little potassium carbonate and cooked with 10 parts of milk. The wheat and malt flour are usually cooked, and sold in powder ready to be boiled with the milk.

Dried Bread.—In addition to biscuit already described, bread has been partially dried by being pressed in an hydraulic press (method of Laignel). Much water flows out, but when taken out the bread still feels moist. In a day or two, however, it becomes as hard as a stone, and in a year's time will be found good and agreeable. Placed in water, it slowly swells. The "pain biscuité" of the French army is bread dried by heat.

Dried Potatoes are sold in two forms—slices and granulated. In either case the potato is easily cooked, and is very palatable. It should be soaked in cold water first for some time, then slowly boiled, or, what is much better,

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[1] Poggiale, *Rec. de Mem. de Méd. Milit.*, Avril 1868, p. 268.

steamed. The directions for cooking Edward's preserved potato (which is granulated) are: "To three-quarters of a pound add about one quart of boiling water, stirring it at the same time; cover it closely; the basin or vessel used should be kept hot; let it stand for ten minutes; then well mash, adding butter, salt, &c., at discretion." It is stated to be equal to six times its bulk of the fresh vegetable, but this is hardly borne out by analysis: four times is as high as it would be safe to allow. The analyses made by Professor Attfield and Dr de Chaumont[1] show that a ℔ of preserved potato contains the solid matter of only 3½ of ordinary fresh potatoes.

Dried Vegetables (*other than Potatoes*).—Dried and compressed vegetables of all kinds (peas, cauliflowers, carrots, &c.) are now prepared, especially by Messrs Masson and Challot, so perfectly that, if properly cooked, they furnish a dish almost equal to fresh vegetables. Professor Attfield found that dried compressed cabbage contained the solids of *seven* times its weight of fresh cabbage, whilst the mixed vegetables contained *five and a half* times the solids of the fresh vegetables. They must be cooked very slowly. If there is any disagreeable taste from commencing putrefaction, which is very rare, a little chloride of lime removes it at once. Potassium permanganate can be also used for this purpose.

As anti-scorbutics they are said to be inferior to the fresh vegetable (experience of American war), but are still much better than nothing.[2]

Dried Apples in slices are now imported largely from America: they are palatable when cooked, and would be a useful article in the field.

Preserved Vegetables, that is, vegetables preserved in their natural condition (cooked), are much to be preferred, both as being more palatable and as being more nutritious and better anti-scorbutics. They occupy, however, much greater bulk.

Various excellent forms of *mixed rations of meat and vegetables* in tins are prepared by *Moir & Son* and others at home and abroad: they are ready cooked and very palatable, and may be eaten either cold or warmed up when that is possible.

Dried Milk.—Preserved milk is sold in a liquid form, but is also sold as a powder, which is very well prepared.

Concentrated Milk.—Milk is evaporated at low steam heat to the consistence of a thick syrup, and white sugar is added. After opening the tins the samples remain good for over a month. The amount of sugar, however, is very large; in one sample it was found to be as much as 16·7 lactin and 60·7 cane sugar. Other samples, such as the Swiss and Bavarian (Lœflund's), are preserved without extra sugar, and are reduced in bulk to ½ or ¼ of the original: these, however, must be used as soon as possible after the tin is opened, for they do not keep like the sweetened preparations.

Dried Eggs.—The yolk is not easily kept after drying, but the white can be so; it is cut into thin scales, and forty-four eggs make about 1 ℔. The yolk and white are also mixed with flour, ground rice, &c., and are then dried.

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[1] *Report of Committee on Scurvy*, 1877.

[2] Professor Attfield (*loc. cit.*) considers that in the compressed vegetables some at least of the juice is lost in the preparation, probably by pressure.

CHAPTER X.

BEVERAGES AND CONDIMENTS.

SECTION I.

ALCOHOLIC BEVERAGES.

Although it is convenient to place all the beverages which contain Alcohol under one heading, they yet differ materially in composition and effects.

Sub-Section I.—Beer.

Composition.—The law formerly allowed only malt and hops to be used in brewing,[1] but sugar (under the name of *saccharum*) is now largely substituted, as well as bitter substances other than hops.

The specific gravity varies from 1006 to 1030, or even more, in the thick German beers; the average in English beers and porters is from 1010 to 1014. The percentage of extract (dextrin, cellulose, sugar, lupulite, and hop resin) is from 4 to 15 per cent. in ale, and from 4 to 9 per cent. in porter. It is least in the bitter, and highest in the sweet ales. The alcohol varies from 1 to 10 per cent. in volume. The free acidity which arises from lactic, acetic, gallic, and malic acids ranges (if reckoned as glacial acetic acid) from 18 to 45 grains per pint. The sugar has a great tendency to form so-called glucinic (or glucic) acid ($C_{12}H_{11}O_9$). There is a small quantity of albuminous matter in most beers, but not averaging more than 0·5 per cent. The salts average 0·1 to 0·2 per cent., and consist of alkaline chlorides and phosphates, and some earthy phosphates. There is a small amount of ammoniacal salt. The dark beers, or porters, contain caramel and assamar. Free carbon dioxide is always more or less present; the average is 0·1 to 0·2 parts by weight per cent., or about 1¾ cubic inch per ounce. Volatile and essential oils are also present.

Adopting mean numbers, 1 pint (20 ounces) of beer will contain—

Alcohol, ...	1 ounce.
Extractives, dextrin, sugar, . . .	1·2 ,, (524 grains).
Free acid, ...	25 grains.
Salts, ...	13 grains.

Physiological Action.—The action on tissue metamorphosis, so far as is known, is supposed to be one of lessened excretion, the urea and pulmonary

[1] In the Licensing Act (1872), clause 19 contains penalties for using any deleterious substance for mixing with liquors sold by persons having licences under the Act, and in the first schedule to the Act is a list of deleterious ingredients, viz.:—"Cocculus indicus, chloride of sodium (otherwise common salt), copperas, opium, Indian hemp, strychnine, tobacco, darnel seed, extract of logwood, salts of zinc or lead, alum, and any other extract or compound of any of the above ingredients." Several articles which are supposed to be used as adulterants are omitted from this list.

carbon dioxide being both decreased. If this be the case, it is not owing to the alcohol, at least in moderate dietetic doses, but to some of the other ingredients; but the experiments require repetition.[1] On the nervous system the action is probably the same as that of alcohol. The peculiar exhausting or depressing action of beer taken in large amount has been ascribed by Ranke[2] to the large amount of potash salts, but probably the other constituents (especially the hop) are also concerned.

When beer is taken in daily excess, it produces gradually a state of fulness and plethora of the system, which probably arises from a continual, though slight, interference with elimination both of fat and nitrogenous tissues. When this reaches a certain point appetite lessens, and the formative power of the body is impaired. The imperfect oxidation leads to excess of partially oxidised products, such as oxalic and uric acids. Hence many of the anomalous affections, classed as gouty and bilious disorders, which are evidently connected with defects in the regressive metamorphosis.

The question, What is excess? is not easy to answer, and will depend both on the composition of the beer and on the habits of life of those who take it; but, judging from the amount of alcohol which is allowable, from one pint to two pints, according to the strength of the beer, is a sufficient amount for a healthy man.

For EXAMINATION of Beer, see BOOK III.

SUB-SECTION II.—WINES.[3]

Composition.

The composition of wine is so various that it is difficult to give a summary. The following are the chief ingredients:—

1. *Alcohol.*—From 6 to 25 per cent., volume in volume, of anhydrous alcohol. It has been, however, stated that the fermentation of the grape, when properly done, cannot yield more than 17 per cent., and that any amount beyond this is added.[4] Some of the finest wines do not contain more than 6 to 10 per cent.

	Per cent. of Alcohol (volume in volume).
Port (*analysed in England*),	16·62[5] to 23·2
Sherry (*analysed in England*),	16 ,, 25
Madeira (*analysed in England*),	16·7 ,, 22
Marsala (*analysed in England*),	15 ,, 25
Bordeaux wines, red (mean of 90 determinations of different sorts: Chateau Lafite, Margaux, Larose, St Emilion, St Estèphe, &c.),	6·85 ,, 13

[1] Binz (*Journal of Anatomy and Physiology*, May 1874) states that alcohol diminishes both the pulmonary carbonic acid and urea.

[2] *Phys. des Menschen*, 1868, p. 139.

[3] For a full account of wines, see the work by Thudichum and Dupré (*Origin, Nature, and Use of Wine*, 1872).

[4] Mulder (*On Wine*, p. 186) quotes Guijal to the effect that pure port never contains more than 12·75 per cent. of pure alcohol; but Mulder doubts this. Dr Gorman stated before the Parliamentary Committee that pure sherry never contains more than 12 per cent. of alcohol, and that 6 or 8 gallons of brandy are added to 108 gallons of sherry. Thudichum and Dupré (*On Wine*, p. 682) state that a natural wine may contain a minimum of 9, while the maximum limit is 16 per cent. (of weight in volume). They also state that a pipe of 115 gallons of port wine has never less than 3 gallons of brandy added to it, and the rich port wines have 13 to 15 gallons added. It would seem that the natural wines of Australia contain a larger quantity of alcohol in some instances than any European wine.

[5] Some port used in the Queen's establishment contained only 16·62, and the highest percentage was 18·8 (Hofmann). The sherry contained only 16 per cent. and the claret 6·85 to 7 per cent. The highest percentage found by Thudichum and Dupré in port wine was 19·2 per cent. of weight in volume = 23·4 per cent. volume in volume.

	Per cent. of Alcohol.
Bordeaux wines, white (mean of 27 determinations of sorts: Sauternes, Barsac, Bergerac, &c.),	11 to 18·7
Rhone wines, red (Hermitage, Montpellier, Frontignan, &c.),	8·7 „ 13·7
Rousillon,	11 „ 16
Burgundy, red (Beaune, Macon),	7·3 „ 14·5
„ white (Chablis, &c.),	8·9 „ 12
Pyrenean,	9 „ 16
Champagnes,	5·8 „ 13
Moselles,	8 „ 13
Rhine wines (Johannisberger, Hochheimer, Rüdesheimer, &c.),	6·7 „ 16
Hungarian wine,	9·1 „ 15
Italian,	14 „ 19
Syria, Corfu, Samos, Smyrna, Hebron, Lebanon,	13 „ 18

So various is the amount of alcohol in wines from the same district, that a very general notion only can be obtained by tables, and a sample of the wine actually used must generally be analysed.

To tell how much pure alcohol is taken in any definite quantity of wine, measure the wine in ounces, multiply it by the percentage of alcohol, and divide by 100.

Example.—Wine drunk being 9 oz., and the percentage 13, then $\frac{9 \times 13}{100}$

$$= 1 \cdot 17 \text{ oz. of absolute alcohol by measure.}$$

The amount of alcohol can be determined by distillation or evaporation, as given in the section on EXAMINATION of Beer, BOOK III. Instruments, however, are required which indicate a less specific gravity than pure water. If the medical officer has only a common urinometer, the only plan will be to dilute with an equal part of pure water at 60°, and then to add a little salt, so as to bring the specific gravity above that of the water; then evaporate as usual. Take the difference of the specific gravities (before and after evaporation); deduct from 1000, and look in the specific gravity table (BOOK III.) for the amount of alcohol in the diluted wine; by multiplying the result by 2 the percentage of alcohol in the undiluted wine is found. Sometimes, besides ethyl alcohol, small quantities of propyl, butyl, and amyl alcohols are found in wine. A little acet-aldehyde is present in some Greek wines (Thudichum and Dupré), but is not considered to indicate unsoundness.[1]

2. *Ethers.*—Œnanthic, citric, malic, tartaric, racemic, acetic, butyric, caprylic, caproic, pelargonic, and many others. Dr Dupré states that there are 25 or even more compound ethers in wine, and some of them are in very small quantities. The "bouquet" of wine is partly owing to the ethers (especially to the volatile), partly, it is said, to extractive matters. Œnanthic ether is that which gives its characteristic odour to wine. Dr Dupré has given a very good plan of estimating the amount of the volatile and non-volatile ethers, but it is too delicate for medical officers.[2]

3. *Albuminous Matters—Extractive Colouring Matter.*—The quantity of albumen is not great; the extractives and colouring matter vary in amount. The colouring matter is derived from the grape-skins; it is naturally greenish or blue, and is made violet and then red by the free acids of wine. The bluish tint of some Burgundy wines is owing, according to Mulder, to the very small

[1] If it is present in white wines (such as Sauterne) it is a certain sign of unsoundness.
[2] *Chem. Journal*, Nov. 1867, and *Origin, Nature, and Use of Wine.*

amount of acetic acids which these wines contain. It is, according to Batilliat, composed of two matters—rosite and purpurite. With age changes occur in the extractive matters; some of it falls (apothema), especially in combination with tannic acid, and the wine becomes pale and less astringent.

4. *Sugar* exists in varying amounts, and in the form, for the most part, of fruit sugar. Sherry generally contains sugar, but not always; it averages 8 grains per ounce,[1] and appears to be highest in the brown sherries, and least in Amontillado and Manzanilla. In Madeira it varies from 6 to 66 grains per ounce; in Marsala a little less; in Port, from 16 to 34 grains per ounce, being apparently greatest in the finest wines. In Champagne it amounts to from 6 to 28 grains, the average being about 24 grains; but a good deal of Champagne is now drunk as "vin brut," without any sugar. In the Clarets, Burgundy, Rhine, and Moselle wines it is absent, or in small amount.

In determining the sugar, if the copper solution be used, the colouring matter is acted on by the alkali of the copper solution, and interferes with the appreciation of the change of tint, and must be got rid of by acetate of lead, animal charcoal, boiling, and filtering. If any substance exists which is still turned green by the alkali of the copper solution, the wine must be neutralised, evaporated to dryness, and the sugar dissolved. As a rule, the copper solution employed directly with wine gives $\frac{1}{2}$ per cent. too much sugar (Fehling), and a correction to this amount should be made.[2]

5. *Fat.*—A small amount exists in some wine.

6. *Free Acids.*—Wine is acid from free acids and from acid salts, as the potassium bitartrate. The principal acids are racemic, tartaric, acetic, malic, tannic (in small quantities), glucic, succinic, lactic (?), carbonic, and fatty acids, such as formic, butyric, or propionic. Some acids are volatile besides the acetic, but it does not seem quite certain what they are. The tannic acid is derived from the skins; it is in greatest amount in new Port wines; it is trifling in Madeira and the Rhine wines; it is present in all white and most red-fruit wines, except Champagne. The tannic acid on keeping precipitates with some extractive and colouring matter (apothema of tannic acid).

7. *Salts.*—The salts consist of bitartrate of potassium, tartrate of calcium and sodium, sulphate of potassium, a little phosphate of calcium and magnesium, chloride of sodium, and iron. The magnesia is in larger amount than the lime, and exists sometimes as malate and acetate. A little manganese and copper have been sometimes found. In Rhine wine a little ammonia is found (Mulder). The total amount of salts is 0·1 to 0·3 per cent. —*i.e.*, about 9 to 26 grains per pint, or $\frac{1}{2}$ to $1\frac{1}{2}$ grains per ounce. The salts can only be detected by evaporation and ignition.

8. The total solids in wine vary from 3 to 14 per cent., or in some of the rich liqueur-like wines to more. The specific gravity depends upon the amount of alcohol and of solids, and varies from 0·673 to 1·002 or more. An approximate notion can be formed of the total solids by taking the specific gravity, after driving off the alcohol by evaporation and then replacing the water.

SUB-SECTION III.—SPIRITS.

The Queen's *Regulations for the Army* (1885, sec. xv. paragraph 70) forbid the sale of spirits in canteens at home, but permit it in foreign stations at the discretion of the commanding officer.

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[1] Bence Jones, in *Mulder on Wine*, p. 386.

[2] The addition of extraneous sugar to wine may be detected by the use of the saccharometer along with Fehling's solution.

Brandy contains, besides alcohol, œnanthic ether, acetic, butyric, and valerianic ethers. Tannin, and colouring matter from the cask, or from caramel, are present. If sugar is present in any quantity, it must have been added. The inferior kinds of brandy, prepared from potatoes as well as grain, contain potato fusel-oil. Rum contains a good deal of butyric ether, to which the aroma is chiefly owing. Gin, besides containing the oil of juniper, is flavoured with various aromatic substances, as *Calamus aromaticus*, coriander, cardamoms, cinnamon, almond-cake, and orange-peel; Cayenne is often added. Whisky often derives a peculiar flavour from the malt being dried over peat fires, or by the direct impregnation of peat smoke.[1] Peach stones and pine sawdust are also said to be added.

Composition of Spirits.

The following table gives the chief points of importance:[2] —

Name.	Sp. gr. at 62° F.	Alcohol per cent.	Solids per cent.	Ash per cent.	Acidity per ounce, reckoned as tartaric acid.	Sugar per cent.
Brandy, . .	0·929–0·934	50–60	1·2	0·05 to 0·2	1 grain	0 or traces
Gin, . . .	0·930–0·944	49–60	1·2	0·1	0·2	1
Whisky, . .	0·915–0·920	50–60	0·6	trace	0·2	0
Rum, . . .	0·874–0·926	60–77	1	0·1	0·5	0

Alcohol as an Article of Diet in Health.[3]

In endeavouring to determine the dietetic value of alcoholic beverages, it is desirable to see, in the first place, what are the effects of their most important constituent, viz., alcohol.

Three sets of arguments have been used in discussing this question, drawn, namely, from—1, the physiological action of alcohol; 2, experience of its use or abuse; and 3, moral considerations.

The last point will not be further alluded to, for without underrating the great weight of the argument drawn from the misery which the use of alcohol produces,—a misery so great that it may truly be said, that if alcohol were unknown, half the sin and a large part of the poverty and unhappiness in the world would disappear,—yet this part of the subject is

[1] It may be worth while to give the names of some of the distilled spirits used in different parts of the world, as the army surgeon may meet with them in the course of service :—

Nations by whom employed.	Name.	Obtained from
Hindus, Malays, &c., . .	Arrack.	Rice or Areca-nut.
Greeks, Turks, &c., . .	Raki.	Rice.
Hindus, ...	Tārī (corrupted to Toddy).	Coco-nut and several other palms.
,, (Mahrattas), . .	Bōjā.	Eleusine Corocana.
,, (Sikkim), . .	Marwa.	,, ,,
Chinese, ...	Samshū.	Rice.
Japanese, ...	Sácie.	...
Pacific Islanders, . .	Kawa.	Macropiper.
Mexicans, ...	Pulque.	Agave.
South Americans, . .	Chica.	Maize.
Tartars, ...	Koumiss.	Mares' milk.
Russians and Poles, . .	Vodka, Raka.	Potato.
Abyssinians, . . .	Tallah.	Millet.

[2] This table is chiefly taken from Bence Jones' *Observations;* Appendix to *Mulder on Wine*, p. 389; and from Hassall's *Food and Adulteration*, p. 645.

[3] The subject of spirits in sickness is another point altogether. Dr Parkes believed they were often of great use, although, like every other strong medicine, they require to be given carefully.

so obvious that it seems unnecessary to occupy space with it. The arguments, however, which are strongest for total abstinence, are drawn from this class. Nor does any one entertain a moment's doubt that the effect of intemperance in any alcoholic beverage is to cause premature old age, to produce or predispose to numerous diseases, and to lessen the chance of living very greatly. The table given below,[1] taken from Neison's *Vital Statistics*, puts this in a strong light.

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[1] Effects of intemperance (Neison's *Statistics*, p. 217 *et seq.*):—

Ratio per cent. from the undermentioned Causes to Deaths from all Causes.

Cause of Death.	1847.	Gotha Life Office.	Scottish Widows' Fund.	Intemperate Lives.
Head diseases, ...	9·710	15·176	20·720	27·10
Digestive organs (especially those of the liver), ...	6·240	8·377	11·994	23·30
Respiratory organs, . . .	33·150	27·843	23·676	22·98
Total of above three classes, .	49·100	51·396	56·390	73·38

It thus appears that the intemperate have a much greater mortality from head and digestive diseases than other classes.

In intemperate persons the mortality at 21–30 years of age is five times that of the temperate; from 30–40 it is four times as great. It becomes gradually less.

A Temperate person's chance of living is,	An Intemperate person's chance of living is,
At 20=44·2 years.	At 20=15·6 years.
,, 30=36·6 ,,	,, 30=13·8 ,,
,, 40=28·8 ,,	,, 40=11·6 ,,
,, 50=21·25 ,,	,, 50=10·8 ,,
,, 60=14·285 ,,	,, 60= 8·9 ,,

All these deductions appear to be drawn from observations on 357 persons with 6111·5 years of life. The facts connected with these persons are well authenticated, but the number is small.

The average duration of life after the commencement of the habit of intemperance is—

Among mechanics, working and labouring men, . . .	18 years.
,, traders, dealers, and merchants, ...	17 ,,
,, professional men and gentlemen, ...	15 ,,
,, females, ...	14 ,,

Those who are intemperate on spirits have a greater mortality than those intemperate on beer.

Those who are intemperate on spirits and beer have a slightly greater mortality than those intemperate on only spirits or beer, but the difference is immaterial.

	Mortality per annum.
Spirit drinkers, ...	5·996 per cent. (nearly 60 per 1000).
Beer drinkers, ...	4·597 per cent. (nearly 46 per 1000).
Spirit and beer drinkers, . .	6·194 per cent. (nearly 62 per 1000).

Very striking evidence in favour of total abstinence, as contrasted with moderation, is given by the statistics of the United Kingdom Temperance and General Provident Institution. One section consists of abstainers, another of persons selected as not known to be intemperate. The claims for five years (1860–70), anticipated in the Temperance section, were £100,446; but there were actually only claims for £72,676. In the general section, the anticipated claims were £196,352; and the actual claims were no less than £230,297. The much greater longevity of the abstainer is better seen by the amount of bonuses paid to each £1000 whole-life policy in the two sections for the same five years:—

Age at Entrance.	Premiums paid.	Bonus added in Temperance Section.	Bonus added in General Section.
	£ s. d.	£ s. d.	£ s. d.
15	83 2 6	61 1 0	35 10 0
20	93 6 8	64 0 0	37 0 0
25	106 9 2	68 10 0	40 0 0
30	122 1 8	74 0 0	43 0 0
35	138 19 2	78 19 0	46 0 0
40	162 5 10	86 0 0	50 4 0
45	188 10 10	92 18 0	54 0 0
50	226 5 0	104 2 0	60 13 0
55	284 3 4	122 14 0	71 11 0

The physiological argument for the use or disuse of alcohol requires to be used with caution, as our knowledge of the action of pure alcohol (much more of the alcoholic beverages) is imperfect.

When taken into the stomach, alcohol is absorbed without alteration, or is perhaps in some small degree converted into acetic acid, possibly by the action of the mucus or secretion of the stomach. The rate of absorption is not known, and it has been supposed that when given in very large quantities it may not be absorbed at all. It has not, however, been recovered from the fæces in any great amount. After absorption it passes into the blood, and then throughout the body; if the observations of Schulinus [1] are correct, it is equally distributed, and does not accumulate, as was formerly supposed, in the liver and nervous tissue. It can easily be detected in all the organs soon after it is taken. It commences to pass out from the body speedily, as it may be detected in the breath soon after it is taken; it emerges by the lungs, by the skin, in smaller quantities by the urine, and slightly by the bowels, or this may be merely from unabsorbed portions passing out. The amount recoverable from all these channels is usually small,[2] but occasionally, when very large quantities have been taken, the kidneys excrete it largely, so that the specific gravity of the urine has been below that of water, and distillation has given an inflammable fluid.[3]

Much debate has taken place as to whether all or how much of the alcohol is thus eliminated, and whether any is destroyed in the body. The experiments of Dr Percy, and subsequently of Strauch, and especially of Masing in Buchheim's laboratory at Dorpat, followed as they were by the confirmatory observations of MM. Perrin, Lallemand, and Duroy, seemed at one time to have settled the question, and to have proved that alcohol is very little or not at all destroyed in the body. Since then the criticisms and experiments of Baudot, and especially the observations of Schulinus,[4] Anstie,[5] Dupré, and Subbotin, have again altered the position, and although the experimental evidence is incomplete (chiefly on account of the difficulty of collecting the amount given off by the lungs and skin), the opinion that some, and perhaps much, alcohol disappears in the body is generally admitted.[6]

At every age, therefore, the abstainer has a very great advantage. Mr Vivian, the President of the Temperance and General Provident Institution, brought before the British Association at Bristol in 1875 the following statistics:—

Years.	Abstinence Section.		General Section.	
	Expected.	Actual.	Expected.	Actual.
1866-70 (5 years),	549	411	1008	944
1871-74 (4 years),	561	390	994	1033
Totals (9 years),	1110	801	2002	1977

On the Gold Coast during the Ashantee war the evidence (slight as it was) was decidedly in favour of the teetotallers (Parkes, *On the Issue of a Spirit Ration*, p. 28, 1875).

[1] *Archiv der Heilk.*, 1866, p. 97.

[2] Experiments on this point by Schulinus, Anstie, Dupré, Thudichum, and others prove that ordinarily the urinary elimination is slight. When it becomes at all marked, or even when it occurs at all, the detection of alcohol by potassium bichromate and sulphuric acid has been proposed by Anstie as an indication of the point when as much alcohol has been taken as can be disposed of by the body.

[3] A good case is given by Dr Woodman (*Medical Mirror*, July 1865).

[4] *Archiv der Heilk.*, 1866.

[5] *Lancet*, 1868.

[6] The amount eliminated by these channels has been variously stated. The latest observa-

If alcohol is destroyed in the body, through what stages does it pass? The statement of Duchek, that it forms aldehyde, has been disproved. Its easiest transformation out of the body is into acetic acid; but when animals are poisoned with alcohol, Buchheim and Masing could detect no acetic acid in the blood; still the amount would be so small it might be overlooked, or the acetic acid might be soon transformed. Lallemand, Perrin, and Duroy could find no oxalic acid. It it be true that the pulmonary carbonic acid is lessened, it cannot be oxidised to carbonic acid and eliminated by the lungs unless the transformation of some other substance ordinarily furnishing carbonic acid is arrested. The mode of destruction is, in fact, unknown. The only point which throws any light upon it is the slight increase of acidity in the urine during the use of alcohol, which looks as if an acid of some kind were formed out of it.

Present experiments show, then, that some portion passes out, and another, and probably the larger portion, is gradually destroyed. The place where the partial destruction of alcohol occurs is yet doubtful; but it is impossible that the transformation takes place in the various gland-cells in which almost all, or all, the changes in the body take place. As the change out of the body which most easily occurs is the formation of acetic acid, it seems at present most likely that some of the alcohol is thus transformed. The acetic acid would then unite with the soda of the blood, and a carbonate would eventually be formed which would be eliminated with

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tions are by Dupré,[1] Anstie, and Subbotin.[2] According to Dupré, from experiments on himself, the amount eliminated by the urine and breath (he did not examine the skin) is only a minute fraction of that taken in, and it takes place chiefly in the first nine hours; subsequently the amount is excessively small. When taken day after day there is no accumulation of alcohol, so that the inference is, that as so little is eliminated almost all must be destroyed. Subbotin's experiments were on rabbits, enclosed in a closed chamber through which the air was slowly drawn. Like Dupré, he determined the amount by oxidising the alcohol obtained into acetic acid by chromic acid; but he found that not inconsiderable quantities (*nicht unbeträchtliche Mengen*) were eliminated through the lungs, and skin, and kidneys in the first five hours. Contrary to Perrin, Lallemand, and Duroy, he found twice as much passed from skin and lungs as from the kidneys. In 11 hours he found 12·6 per cent. was eliminated, and in 24 hours 16 per cent., and he gives reasons for supposing that the difficulties of the experiments (viz., the difficulty of changing all the alcohol into acetic acid; of obtaining the alcohol from the chamber; of regulating the ventilation; and by the diminution of absorption at the end of the experiment, and by the limited time the experiment could be carried on) made the amount actually recovered far less than it should have been. Anstie made numerous experiments on the urine and sweat, and always found the quantities very minute.

With regard to the length of time the elimination goes on, Dupré found it to be finished within a few hours; Subbotin found that the elimination was not quite ended in 24; Perrin, Lallemand, and Duroy found it to go on for 32 hours. The late Dr Parkes and Count Wollowicz found that minute quantities could be found in the urine even on the fifth day after a large quantity of brandy had been taken, though the elimination by the lungs ceased much sooner. In some later experiments, with small quantities of beer and wine, Dr Parkes found the elimination to be finished in 24 hours.

Lieben noticed some years ago, that a substance which had some of the characters of alcohol was found in the urine of persons and animals who had taken none. Dr Parkes and Count Wollowicz noticed on one occasion that a substance which slightly reduced chromic acid was obtained from the sweat of a man who had taken no alcohol,[3] though in other cases (E. Smith, *British Medical Journal*, Nov. 2, 1861) there is certainly no substance of this kind in the sweat. Dupré also found in the urine a substance furnishing acetic acid, forming iodoform, and having a lower specific gravity and a higher vapour tension than pure water. The amount of this substance is so minute that its nature cannot be perfectly made out, but Lieben considers it not to be alcohol, but perhaps to be derived from the odoriferous principles of the urine. Dupré doubts this, and Dr Parkes' observation on the sweat shows that it can hardly be so, unless the same odorous substances are passing off by the skin. Dr Parkes doubted whether it was an invariable constituent of urine, as he could find none in the urines of three teetotallers which were examined.

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[1] *Proceedings of Royal Society*, No. 138 (p. 268, 1872). [2] *Zeitschrift für Biol.*, Band vii. p. 361 (1872).
[3] *Proceedings of Royal Society*, No. 113, p. 87 (1870).

the urine, as in the case when acetates are taken.[1] This would account for the pulmonary carbonic acid not being increased. If this view be correct, the use of alcohol in nutrition would be limited to the effects it produces, first as alcohol, and subsequently as acetic acid, when it neutralises soda, and is then changed into carbonate.

The first point only (its effects as alcohol) need be considered—

Influence of Alcohol on the Organs.

1. *On the Stomach.*—In very small quantities it appears to aid digestion; in larger amount it checks it, reddens the mucous membrane, and produces the "chronic catarrhal condition" of Wilson Fox, viz., increase of the connective tissue between the glands; fatty and cystic degeneration of the contents of the glands, and, finally, more or less atrophy and disappearance of these parts.[2] Taken habitually in large quantities it lessens appetite.

2. *On the Liver.*—The action of small quantities on the amount of bile, or glycogenic substances, or on the other chemical conditions of the liver, is not known. Applied directly to the liver by injection into the portal vein, it increases the amount of sugar (Harley). Taken daily in large quantities, it causes either enlargement of the organ by producing albuminoid and fatty deposit, or it causes at once, or following enlargement, increase of connective tissue, and, finally, contraction of Glisson's capsule, and atrophy of the portal canals and cells, by the pressure of a shrinking exudation. The exact amount necessary to produce these changes in the liver and stomach has not yet been fixed with precision.

3. *On the Spleen.*—Its action is not known.

4. *On the Lungs.*—It is said to lessen the amount of carbon dioxide (and of watery vapour?) in the air of expiration,[3] though there are some discrepancies in experiments with different kinds of spirits. E. Smith, for example, found the expired carbon dioxide lessened by brandy and gin, but increased by rum. It is very important these experiments should be repeated, but they show, at any rate, that the usual effect is not to increase the carbon dioxide.[4] In large quantities habitually taken it also alters the molecular constitution of the lungs, as chronic bronchitis and lobar emphysema are certainly more common in those who take much alcohol.

5. *On the Heart and Blood-Vessels.*—Alcohol in healthy persons at first increases the force and the quickness of the heart's action. Dr Anstie[5] confirmed this opinion by careful sphygmographic observations; these effects are still more marked in febrile diseases if alcohol acts favourably (in some

[1] In experiments on large quantities of alcohol, Dr Parkes found the acidity of the urine slightly increased. This would quite agree with the above view, as the union of the acetic acid or carbonic acid formed from it, with some of the alkali ordinarily united to other acids, would increase the urinary acidity. This case is, of course, not parallel with that of acetate of potash given by the mouth, which makes the urine alkaline from carbonate, as some alkali in that case is introduced.

[2] These changes were considered by Wilson Fox to be closely allied with those occurring in cirrhosis of the liver, and in the contracted and indurated kidney. See *Diseases of the Stomach*, 3rd edition, p. 125, footnote; and also *Reynolds' System of Medicine*, vol. ii. p. 869, and footnote.

[3] The effect of red and white French wines and of beer has been very carefully examined by Perrin (*Rec. de Mém. de Méd. Mil.*, 1865, p. 82); a very great diminution in the amount of carbonic acid (from 5·6 to 22 per cent. less being excreted) was noticed in all the experiments. The effect commenced soon, and reached it maximum in the third hour, and ceased in two hours more. The pulse after meals with and without wine had equal power, but after a time the pulse fell more when wine was not taken.

[4] See Binz, *Journal of Anatomy and Physiology*, May 1874.

[5] In a paper read before the British Association in 1868 (*Medical Times and Gazette*, September 1868). This paper shows that the sphygmographic indications (combined with the urinary test) may give us a clue to the often difficult question whether alcohol is doing good or harm in disease.

febrile cases it appears, from Anstie's observations, not to increase the power of the heart). In a healthy man, Dr Parkes found that brandy[1] augmented the rapidity of the pulse 13 per cent., and the force was also increased; taking the usual estimate of the heart's work, its daily excess of work, with 4·8 fluid ounces of absolute alcohol, was equal to 15·8 tons lifted one foot. With claret the results were almost identical. The period of rest of the heart was shortened, and its nutrition must therefore have been interfered with. In another man, Dr Parkes found from 4 to 8 ounces of brandy produced palpitation and breathlessness. Alcohol causes evident dilatation of the superficial vessels, as shown by the redness and flushing of the skin; and in these experiments sphygmographic observations also proved that the arteries dilated more easily before the fuller current thrown out by the stronger acting heart. If it were not for this yielding of the vessels (produced perhaps by paralysis of the vasomotor nerves) alcohol would be a most dangerous agent, as either the strong wave would break the vessel, or the heart would not be properly emptied of the blood during the contraction. It seems likely, therefore, that there must be danger in the use of alcohol when the arteries become rigid in advancing life, if the heart is then susceptible to the action of alcohol. Eventually the vessels of the surface pass into a state of permanent slight enlargement and turgescence; the skin alters in appearance; and owing to this, persons who take much alcohol soon get the appearance of age. In some diseases, alcohol is said to lessen the frequency of the heart's action; and Anstie found it increase arterial tension. In such cases there must be peculiar nervous conditions with which we are unacquainted. Dr Parkes found it usually, if not always, increase the frequency of the heart in disease, and in some patients the rapidity of the heart's action was simply owing to the administration of alcohol. Anstie believed its principal action was on the sympathetic nerve, and the vascular phenomena seem to strengthen this view, while others think it acts especially on the vagus and the heart alone.

6. *On the Blood.*—The amount of fat is either increased, or it is more visible. The chemical changes in the blood are partially arrested.[2]

7. *On the Nervous System.*—In most persons it acts at once as an anæsthetic, and lessens also the rapidity of impressions, the power of thought, and the perfection of the senses. In other cases it seems to cause increased rapidity of thought, and excites imagination, but even here the power of control over a train of thought is lessened. In no case does it seem to increase accuracy of sight; nor is there any good evidence that it quickens hearing, taste, smell, or touch; indeed, Edward Smith's experiments show that it diminishes all the senses. In almost all cases moderate quantities cause a feeling of comfort and exhilaration, which ensues so quickly as to make it probable the local action on the nerves of the stomach has at first something to do with this. Afterwards the increased action of the heart may have an effect. Different spirits act differently on the nervous system, owing probably to the presence of the ethers and oils; some, as samshū[3]

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[1] See papers by Dr Parkes and Count Wollowicz, in *Proceedings of Royal Society*, No. 120 and 132; and another paper by Dr Parkes, No. 136, for the effect of alcohol on the heart during exercise.

[2] Harley, *Proceedings of Royal Society*, March 1865, No. 62, p. 160.

[3] Dr Dupré analysed for Dr Parkes a specimen of the best samshū from Singapore. It contained in 100 c.c. 23·91 per cent. of alcohol by weight, and this was made up of 23·874 parts of ethyl alcohol, and 0·036 parts of amylic alcohol; the amount of free acid (almost all acetic) was 0·105; of residue (sugar almost entirely) 6·01, and of ash 0·06 per cent. Cheap samshū gave nearly the same result. There seems to be nothing deleterious here; and from inquiries among soldiers who have served in Hongkong, it seems doubtful whether good samshū does produce the effects ascribed to it. It is probably the adulterated (with opium,

and raki, produce great excitement, followed by profound torpor and depression. Absinthe is also especially hurtful, apparently from the presence of the essential oils of anise, wormwood, and angelica, as well as from the large amount of alcohol. It appears that the properties of absinthe are somewhat different according to the manner in which water is mixed with it, *i.e.*, suddenly or slowly; in the latter case the particles of the absinthe are more divided, are absorbed more easily, and produce greater effects. In all these cases there can be little doubt that alcohol enters into temporary combination with the nervous structure; and the evidence from the impairment of special sense and muscular power implies that it interferes with the movements of the nervous currents.

8. *On the Muscular System.*—Voluntary muscular power seems to be lessened, and this is most marked when a large amount of alcohol is taken at once; the finer combined movements are less perfectly made. Whether this is by direct action on the muscular fibres, or by the influence on the nerves, is not certain. In very large doses it paralyses either the respiratory muscles or the nerves supplying them, and death sometimes occurs from the impairment to respiration.

9. *On the Metamorphosis of Tissue.*—This is usually stated to be lessened, and it has been said that there is a diminution in the elimination of nitrogen (as urea) and of carbon (as carbon dioxide). But the experiments already referred to by Count Wollowicz and Dr Parkes[1] prove that the metamorphosis of the nitrogenous tissues is in no way interfered with by dietetic doses. Whether the carbon dioxide excretion is really lessened may also be questioned.

10. *On the Temperature of the Body.*—When alcohol is given to healthy animals in full but not excessive doses, the temperature of the body falls. This seems to be shown conclusively by the experiments of Ringer and Rickards, Richardson, Binz, Cuny-Bouvier, and Ruge. In healthy men who have been accustomed to take alcohol in moderate quantities the results are rather contradictory. In a man accustomed to alcohol, Ringer found no change; in two men, temperate, but accustomed to take beer and sometimes spirits, Dr Parkes could not detect any raising or lowering of the thermometer either in the axilla or rectum.[2] Dr Mainzer found no fall of temperature[3] in trials on himself, but a slight fall in another healthy person. Some experiments by Obernier[4] and by Fokker[5] are also quite negative. On the other hand, Ringer, Binz, and Bouvier noticed in some healthy persons a decrease of temperature; and though some of the experiments are evidently rather inaccurate, and though the fall of temperature was inconsiderable, it is difficult to refuse belief that in some cases there may be a slight depression of temperature.[6]

In febrile cases the evidence is almost equally divided. In a man on whom Dr Parkes was experimenting, an attack of catarrh came on with rise of temperature, and alcohol did not apparently affect the heat in the least.

&c.) article which acts so violently. The Cape brandy is of two kinds—the Cape and the Boer brandy; the latter is stronger, and is sometimes called peach brandy; this appears to be the hurtful kind.

[1] *Proceedings of Royal Society*, Nos. 120-123 and 136. [2] *Ibid.*

[3] *Ueber die Einwirkung des Alkohols*, Inau'. Diss. Bonn, 1870.

[4] *Archiv für die ges. Phys.*, Band ii. p. 494.

[5] Quoted by Husemann, *Jahresb. für die ges. Med.*, 1871, Band i. p. 324.

[6] Binz (*loc. cit.*) finds that small (dietetic ?) doses produce no change; large inebriating doses produce a fall from 3°·5 to 5° F., lasting for four or five hours. Habit, however, produces tolerance. In the body, after death, the temperature often rises, but if alcohol has been administered previously it does not do so,—hence Binz concludes that the effect is arrest of chemical changes in the glands.

O. Weber, Obernier, and Rabow were equally unsuccessful in noting a fall in temperature. Binz and C. Bouvier[1] have, however, produced septic fever in animals, and then lowered the febrile heat by large doses of alcohol, in what appears to have been an unmistakable manner, in several cases.

We may conclude that the effect of moderate doses on temperature in healthy men is extremely slight; there is no increase, and in many persons no decrease. In those in whom there is a slight decrease, the amount is trifling.

11. *On the Action of the Eliminating Organs.*—The water of the urine and the acidity are slightly increased; but Dr Parkes found other ingredients were unaffected. The condition of the skin is not certain. Dr E. Smith thought the perspiration lessened, but Weyrich noticed, after spirits, beer, and wine, a large increase in the insensible cutaneous perspiration; and the enlargement of the vessels of the skin would probably lead to increased transit of fluid.

12. *Remote Effects of Alcohol.*—The degenerative changes which occur so frequently in the stomach, liver, and other organs by the constant introduction of improper quantities of alcohol into the body,[2] affect also almost all parts of the body. The brain and its membranes, and its vessels, suffer early and principally; and Kremiansky[3] has produced hæmorrhagic meningitis, and pathological changes in the brain-vessels and membranes in dogs by giving them alcohol.[4] There is no question that several brain diseases, including some cases of insanity, are produced by excess of alcohol.[5] So, also, degenerative changes in the stomach, liver, lungs, and probably in the kidneys[6] result from immoderate use. To use Dickinson's expressive phrase, alcohol is the very "genius of degeneration." And these alcoholic degenerations are certainly not confined to the notoriously intemperate. They have been seen in women accustomed to take wine in quantities not excessive, and who would have been shocked at the imputation that they were taking too much, although in their case the result proved that for them it was excess. The nature of the degenerative changes appear to be in all cases the same, viz., fibroid and fatty changes.

Considering, also, the great increase in the action of the heart, and the dilatation of the vessels, it can scarcely be doubted that alcohol in excess is one of the agencies causing disease of the circulatory organs.

Is Alcohol desirable as an Article of Diet in Health?

This question is so large and difficult that a satisfactory answer can hardly be given with our present knowledge. The data for passing a judgment are partly physiological, but still more largely empirical.

The obvious useful physiological actions of alcohol are an improvement in appetite, produced by small quantities, and an increased activity of the circulation, which, within certain limits, may be beneficial. It is difficult to perceive proof at present of any other useful action, since it is uncertain

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[1] See especially *Pharmakologische Studien über den Alkohol*, von C. Bouvier, Berlin, 1872.

[2] A very striking paper on this subject has been published by Dickinson (*Lancet*, November 1872). It paints, in startling colours, the immense degenerative power of alcohol.

[3] Virchow's *Archiv*, Band xlii. p. 338.

[4] See also the experiments by Magnan (*Sur l'Alcoolisme*).

[5] Magnan states the two terminations of chronic alcoholism to be *dementia* and *general paralysis*.

[6] Anstie and Dickinson have denied that the kidneys suffer in alcoholism in any great degree. It is an open question; but the evidence is in favour of kidney degeneration being one of the effects of alcoholism. Dr George Johnson states that out of 200 patients with Bright's disease from all causes, he found no less than 58 were drunkards.

whether, during its partial destruction in the system, it gives rise to energy. In cases of disease, in addition to its effect on digestion and circulation, its narcotising influence on the nervous system may be sometimes useful. Beale suggests that it may restrain the rapidity of abnormal growth or development of multiplying cells, and that by such arrest it may possibly diminish bodily temperature; but proof of this has not been given.

The dangerous physiological actions in health, when its quantity is larger, are evidently its influence on the nervous system generally, and on the regulating nerve-centres of the heart and vaso-motor nerves in particular;[1] the impairment of appetite produced by large doses; the lessening of muscular strength; and remotely the production of degenerations. Except when it lessens appetite, it does not alter the transformation of the nitrogenous tissues and the elimination of nitrogen; nor can it be held to be absolutely proved to lessen the excretion of carbon. If it did so, this effect in health would be simply injurious.

It is a matter of the highest importance to determine when the limit of the useful effect of alcohol is reached. The experiments are few in number, but are tolerably accurate. From experiments made by Dr Anstie, an amount of one fluid ounce and a half (42·6 c.c.) caused the appearance of alcohol in the urine, which Anstie regards as a sign that as much has been taken as can be disposed of by the body. The late Dr Parkes and Count Wollowicz obtained almost precisely the same result. When only one fluid ounce of absolute alcohol was given none could be detected in the urine. They found that in a strong healthy man, accustomed to alcohol in moderation, the quantity given in twenty-four hours that begins to produce effects which can be considered injurious is something between one fluid ounce (=28·4 c.c.) and two fluid ounces (56·7 c.c.). The effects which can then be detected are slight but evident narcosis, lessening of appetite, increased rapidity of rise in the action of the heart, greater dilatation of the small vessels as estimated by the sphygmograph, and the appearance of alcohol in the urine. These effects manifestly mark the entrance of that stage in the greater degrees of which the poisonous effects of alcohol become manifest to all.

It may be considered, then, that the limit of the useful effect is produced by some quantity between 1 and 1½ fluid ounces in twenty-four hours. There may be persons whose bodies can dispose of larger quantities; but as the experiments were made on two powerful healthy men, accustomed to take alcohol, the average amount was more likely to be over than under stated. In women, the amount required to produce decided bad effects must, in all probability, be less. For children, there is an almost universal consent that alcohol is injurious, and the very small quantity which produces symptoms of intoxication in them indicates that they absorb it rapidly and tolerate it badly.

Assuming the correctness of these experimental data, which, though not extensive, are yet apparently exact, it is evident that moderation must be something below the quantities mentioned; and considering the dangers of taking excess of alcohol, it seems wisest to assume 1 to 1½ fluid ounces of absolute alcohol in twenty-four hours as the maximum amount which a

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[1] This influence is probably a paralysing agency, arising from a direct though transitory union of the alcohol with the nervous substance. Richardson has made the very important discovery that the alcohols, such as the butyl, amyl, and hexyl alcohols, which contain more carbon, produce a much greater effect on the nervous system than methyl and ethyl alcohol. There are greater muscular tremors and stupor, and these effects increase regularly with the increase of carbon and lessening volatility.

healthy man should take. It must be admitted that this is provisional, and that more experiments are necessary; but it is based on the only safe data we possess. One ounce is equivalent to 2 fluid ounces of brandy (containing 50 per cent. of alcohol); or to 5 ounces of the strong wines (sherries, &c., 20 per cent. of alcohol); or to 10 ounces of the weaker wines (clarets and hocks, 10 per cent. of alcohol); or to 20 ounces of beer (5 per cent. of alcohol). If these quantities are increased one half, $1\frac{1}{2}$ ounces of absolute alcohol will be taken, and the limit of moderation for strong men is reached. This standard appears to be fairly correct; since, from inquiries of many healthy men who take alcohol in moderation, Dr Parkes found that they seldom exceeded the above amounts. Women, no doubt, ought to take less; and alcohol in any shape only does harm to healthy children.

Another question now arises, to which it is more difficult to reply. Is alcohol, even in this moderate amount, necessary or desirable? are men really better and more vigorous, and longer lived with it than they would be without any alcohol? If distinctly hurtful in large quantities, is it not so in these smaller amounts?

There is no difficulty in proving, statistically, the vast loss of health and life caused by intemperance; and the remarkable facts of the Provident Institution show the great advantage total abstainers have over those who, though not intemperate, use alcohol more freely. But it is almost impossible, at present, to compare the health of teetotallers with those who use alcohol in the moderate scale given above. In both classes are found men in the highest health, and with the greatest vigour of mind and body; in both are to be found men of the most advanced age. If the question is looked at simply as a scientific one, it is hardly possible at present to give an answer. Failing in accurate information on this point, the usual arguments for and against the use of alcohol cannot be held to settle the point. These are—

(*a*) That the universality of the habit of using some intoxicating drink proves utility. This seems incorrect,[1] since whole nations (Mohammedan and Hindoo) use no alcohol or substitute; and since the same argument might prove the necessity of tobacco, which, for this generation at any rate, is clearly only a luxury. The wide-spread habit of taking intoxicating liquids merely proves that they are pleasant.

(*b*) That if not necessary in healthy modes of life, alcohol is so in our artificial stage of existence amid the pressure and conflict of modern society. This argument is very questionable, for some of our hardest workers and thinkers take no alcohol. There are also thousands of persons engaged in the most anxious and incessant occupations who are total abstainers, and, according to their own account, with decided benefit.

(*c*) That though it may not be necessary for perfectly healthy persons, alcohol is so for the large class of people who live on the confines of health, whose digestion is feeble, circulation languid, and nervous system too excitable. It must be allowed there are some persons of this class who are benefited by alcohol in small quantities, and chiefly in the form of beer or light wine. Unless these persons wilfully deceive themselves, they feel better, and are better with a little alcohol.

(*d*) That common experience on the largest scale shows that alcohol in not excessive quantities cannot be an agent of harm; that it is and has been used by millions of persons who appear to suffer no injury, but to be in many cases benefited, and therefore that it must be in some way a valuable adjunct

[1] Most nations, however, if not all, use some sedative which may be considered to take the place of alcohol (F. de C.).

to food. A grand fact of this kind must, it is contended, override all objections based on physiological data, which are confessedly incomplete, and which may have left undiscovered some special useful action. It must be admitted that this is a very strong argument, and that it seems incredible that a large part of the human race should have fallen into an error so gigantic as that of attributing great dietetic value to an agent which is of little use in small quantities and is hurtful in large. At first sight the common sense of mankind revolts at such a supposition, but the argument, though strong, is not conclusive; and unfortunately we know that in human affairs no extension of belief, however wide, is *per se* evidence of truth.

(*e*) That though a man can do without alcohol under ordinary circumstances, there are certain conditions when it is useful. It will be necessary to see, then, what is the evidence on this point.

Evidence on the Use of Alcohol under certain Conditions.[1]

Great Cold.—There is a singular unanimity of opinion on this point; all observers condemn the use of spirits, and even of wine or beer, as a preventive against cold. In the Arctic regions we have on this head the evidence of Sir John Richardson, Mr Goodsir (in Sir J. Franklin's first voyage), Dr King, Captain Kennedy (in the last search for Sir J. Franklin, when the whole crew were teetotallers), Dr Rae, Dr Kane, Dr Hayes (surgeon of the Kane expedition), and others. Dr Hayes, indeed, says in his last paper (1859) that he will not only not use spirits, but will take no man accustomed to use them; and that if " imperious necessity obliges him to give spirits, he will give them in small doses frequently, as the excitant action is followed by a very dangerous depression.[2] In the Antarctic regions, and in the cold whaling grounds, we have the strong evidence of Dr Hooker to the same purport, and the customs of the many teetotal whalers. Ulloa long ago noticed the same thing in the ascent of Pichincha.[3] In North America the Hudson's Bay Company entirely excluded spirits, partly, no doubt, to prevent their use among the Indians, but partly, in all probability, from experience of their inutility. Dr Carpenter quotes from Dr Knüll a statement that the Russian army on the march in cold weather not only use no spirits, but no man who has lately taken any is allowed to march. The guides at Chamouni and the Oberland, when out in the winter, have invariably found spirits hurtful; they take only a little light wine (Forbes). The bathing men at Dieppe, who are much exposed to cold from long standing in the sea, also find that spirits are hurtful, and take only a little weak wine (Lévy).

Great Heat.—The evidence here also is almost equally conclusive against the use of spirits or beverages containing much alcohol. Dr Carpenter has assembled the most conclusive testimony from India, Brazil, Borneo, Africa, and Demerara. The best authorities on tropical diseases speak as strongly—Robert Jackson, Ranald Martin, Henry Marshall, and many others. It seems

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[1] See Carpenter's *Essay on Temperance*, and his other writings, and also Spencer Thomson's useful work on the same subject, as well as many other writers.

[2] Some Arctic voyagers, however, are strongly impressed with the value of rum under certain circumstances (Admiral Richards). The experience of the expedition of 1875–76 seems to have shown that it was partially useful given the last thing at night, as enabling the men to get off their frozen clothing, but it had no effect in warding off scurvy. Binz says that alcohol may be useful in damp and cold, because the tissue change is greater, and we can thus moderate it.

[3] He says (Adams' translation, 1807, vol. i. p. 219): "At first we imagined that drinking strong liquors would diffuse a heat through the body, and consequently render it less sensible of the painful sharpness of the cold; but to our surprise we felt no manner of strength in them, nor were they any greater preventative against the cold than common water."

quite certain, also, that not only is heat less well borne, but that insolation is predisposed to.

The common notion that some form of alcoholic beverage is necessary in tropical climates is a mischievous delusion. In the 84th Regiment, in which Dr Parkes formerly served, which from the years 1842 to 1850 numbered many teetotallers (at one time more than 400) in its ranks, the records showed that, both on common tropical service and on marches in India, the teetotallers were more healthy, more vigorous, and far better soldiers than those who did not abstain.[1] The experience of almost every hunter in India will be in accordance with this.

On this point the greatest army surgeons have spoken strongly (Jackson especially, and Martin); and yet officers may still be heard, both in India and the West Indies, to assert that the climate requires alcohol. These are precisely the climates where alcohol is most hurtful.[2]

With regard to service and exercise in the tropics we have the strong testimony of Ranald Martin that warm tea is the best beverage; and this will be corroborated by every one who has made long marches, or hunting excursions, in India, and has carefully observed what kind of diet best suited him.

To cite a well-known individual instance of great exertion in a hot climate, Robert Jackson marched 118 miles in Jamaica, carrying a load equal to a soldier's, and decided that "the English soldier may be rendered capable of going through the severest military service in the West Indies; and that temperance will be one of the best means of enabling him to perform his duty with safety and effect. The use of ardent spirits is not necessary to enable a European to undergo the fatigue of marching in a climate whose mean temperature is from 73° to 80°. I have always found the strongest liquors the most enervating."

Bodily Labour.—A small quantity of alcohol does not seem to produce much effect, but more than two fluid ounces manifestly lessens the power of sustained and strong muscular work. In the case of a man on whom Dr Parkes experimented, 4 fluid ounces of brandy (= 1·8 fluid ounces of absolute alcohol) did not apparently affect labour, though it could not be affirmed it did not do so; but 4 ounces more given after four hours, when there must have been some elimination, lessened muscular force; and a third 4 ounces, given four hours afterwards, entirely destroyed the power of work. The reason was evidently twofold. There was, in the first place, narcosis and blunting of the nervous system—the will did not properly send its commands to the muscles, or the muscles did not respond to the will; and, secondly, the action of the heart was too much increased, and induced palpitation and breathlessness, which put a stop to labour. The inferences were, that even any amount of alcohol, although it did not produce symptoms of narcosis, would act injuriously, by increasing unnecessarily the action of the heart, which the labour alone had sufficiently augmented.[3] These experiments

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[1] See Carpenter's *Physiology of Temperance* for full details. The officers, who, by their example and precept, produced this great effect in a regiment in India, and proved that men are healthier and happier in India without any alcoholic beverage, were Lieut.-Colonel Willington, Captain (afterwards General Sir David) Russell, and Lieut. and Adjutant Seymour, an officer of the greatest promise, who died from dysentery contracted during the mutiny.

[2] Binz holds that in hot climates, or in hot weather, it is pernicious, as interfering with the tissue change, which is already insufficient.

[3] In experimenting on another healthy man the following interesting result was obtained:—The exercise and diet being uniform during a period of ten days, the mean daily pulse (nine two-hourly observations) was 70·65. Severe exercise being then taken during another period of ten days for two hours in the morning, in addition to what had previously been

are in accord with common experience, which shows that men engaged in very hard labour, as iron-puddlers, glass-blowers, navvies on piece-work, and prize-fighters during training, do their work more easily without alcohol.

In the exhaustion following great fatigue, alcohol may be useful or hurtful according to circumstances. If exertion must be resumed, then the action of the heart can be increased by alcohol and more blood sent to the muscles; of course, this must be done at the expense of the heart's nutrition, but circumstances may demand this. In the case of an army, for example, called on to engage the enemy after a fatiguing march, alcohol might be invigorating. But the amount must be small, *i.e.*, much short of producing narcosis (not more than ½ fluid ounce of absolute alcohol), and, if possible, it should be mixed with Liebig's meat extract, which, perhaps on account of its potash salts, has a great power of removing the sense of fatigue.

About two ounces of red claret wine with two teaspoonfuls of Liebig's extract and half pint of water is a very reviving draught, and if it could be issued to troops exhausted by fatigue, would prove a most useful ally.

But when renewed exertion is not necessary it would appear most proper after great fatigue to let the heart and muscles recruit themselves by rest; to give digestible food, but to avoid unnecessary and probably hurtful quickening of the heart by alcohol.

Mental Work.—In spite of much large experience, it is uncertain whether alcohol really increases mental power. The brain circulation is no doubt augmented in rapidity; the nervous tissues must receive more nutriment, and for a time must work more strongly. Ideas and images may be more plentifully produced, but it is a question whether the power of clear, consecutive, and continuous reasoning is not always lessened. In cases of great exhaustion of the nervous system, as when food has been withheld for many hours and the mind begins to work feebly, alcohol revives mental power greatly, probably from the augmented circulation. But, on the whole, it seems questionable whether the brain finds in alcohol a food which by itself can aid in mental work.

Deficiency of Food.—When there is want of food, it is generally considered that alcohol has a sustaining force, and possibly it acts partly by keeping up the action of the heart, and partly by deadening the susceptibility of the nerves. It was formerly supposed that it lessened tissue-change, and thus curtailed the waste of the body; but this is not true of the nitrogenous tissues, and it is not yet quite certain in respect of the carbonaceous. It seems unlikely that alcohol would be applied differently during starvation and during usual feeding.

Cases are recorded in which persons have lived for long periods on almost nothing but wine and spirits. In most cases, however, some food has been taken, and sometimes more than was supposed, and in all instances there has been great quietude of mind and body. It seems very doubtful whether in any case nothing but alcohol has been taken; and, in fact, we may fairly demand more exact data before weight can be given to this statement.

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taken, the pulse in those two hours was augmented 16 beats per minute over the corresponding period; it fell, however, in the subsequent hours below the mean of the corresponding period, so that the mean pulse of the day was 70·42 per minute, the same as in the ten days' period before the additional exercise. The heart, in fact, completely compensated itself, and the work done by it was the same on days of moderate and of severe exercise. Now alcohol would have disturbed this adjustment, and would have kept the heart beating more rapidly than it should do. The compensation would not have been produced. In more recent experiments, in which the effects of rum, meat extract, and coffee were observed, it was found that marching was done least easily with rum, the stimulant effect passing quickly off, and leaving the man less able to finish the work before him.—(*On the Issue of a Spirit Ration in the Ashanti Campaign*, Parkes, 1875.)

The Exposures and Exertions of War.—On this point also there is considerable unanimity of opinion. The greatest fatigues, both in hot and cold climates, have been well borne—have been, indeed, best borne—by men who took no alcohol in any shape, and some instances may be quoted.

In the American War of Independence in 1783, Lord Cornwallis made a march over 2000 miles in Virginia, under the most trying circumstances of exposure to cold and wet; yet the men were remarkably healthy, and among the causes for this health, Chisholm states that the necessary abstinence from strong liquors was one.

In 1794-95 occurred the Maroon war in Jamaica, where, almost for the first time in West Indian warfare, the troops were remarkably healthy, though the campaign was very arduous and in the rainy season, and there were no tents. The perfect health of the troops may partly have been owing to the climate of the hills (2000 feet above the sea), but it was chiefly attributed to the fact that the men could obtain no spirits or alcoholic liquor of any kind.

In 1800, an English army proceeding from India to Egypt to join Sir Ralph Abercromby, marched across the desert, from Kossier on the Red Sea, and descended the Nile for 400 miles. Sir James M'Grigor[1] says that the fatigue in this march has, perhaps, never been exceeded by any army, and goes on to remark:—

"We received still further confirmation of the very great influence which intemperance has as a cause of disease. We had demonstration how very little spirits are required in a hot climate to enable a soldier to bear fatigue, and how necessary a regular diet is.

"At Ghenné, and on the voyage down the Nile (on account of the difficulties of at first conveying it across the desert), the men had no spirits delivered out to them, and I am convinced that from this not only did they not suffer, but that it even contributed to the uncommon degree of health which they at this time enjoyed. From two boats the soldiers one day strayed into a village, where the Arabs gave them as much of the spirit which they distil from the juice of the date-tree as induced a kind of furious delirium. It was remarked that, for three months after, a considerable number of these men were in the hospitals."

Dr Mann,[2] one of the few American surgeons in the war of 1813-14 who have left any account of that contest, thus writes:—

"My opinion has long been that ardent spirits are an unnecessary part of a ration. Examples may be furnished to demonstrate that ardent spirits are a useless part of a soldier's ration. At those periods during the revolutionary war, when the army received no pay for their services, and possessed not the means to procure spirits, it was healthy. The 4th Massachusetts Regiment, at the eventful period when I was the surgeon, lost in three years by sickness not more than five or six men. It was at a time when the army was destitute of money. During the winter 1779-80 there was only one occurrence of fever in the regiment, and that was a pneumonia of a mild form. It was observable in the last war, from December 1814 to April 1815, the soldiers at Plattsburgh were not attacked with fevers as they had been the preceding winters. The troops during this period were not paid—a fortunate circumstance to the army, arising from want of funds. This embarrassment, which was considered a national calamity, proved a blessing to the soldier. When he is found poor in money, it is always the case that he abounds in health—a fact worth recording."

No testimony can be stronger than that given by the late Inspector-General Sir John Hall, K.C.B. He says:[3]—

"My opinion is, that neither spirit, wine, nor malt liquor is necessary for health. The healthiest army I ever served with had not a single drop of any of them; and, although it was exposed to all hardships of Kaffir warfare at the Cape of Good Hope, in wet and inclement weather, without tents or shelter of any kind, the sick-list seldom exceeded 1 per cent.; and this continued not only throughout the whole of the active

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[1] *Medical Sketches of the Expedition to Egypt*, p. 10.
[2] Hamilton, *Military Surgery*, p. 61.
[3] *Medical History of the War in the Crimea*, vol. i. p. 504.

operations in the field during the campaign, but after the men were collected in standing camps at its termination; and this favourable state of things continued until the termination of the war. But immediately the men were again quartered in towns and fixed posts, where they had free access to spirits, an inferior species of brandy sold there, technically called 'Cape Smoke,' numerous complaints made their appearance among them.

"In Kaffraria the troops were so placed that they had no means of obtaining liquor of any kind; and all attempts of the 'Winklers' to infringe the police regulations were so summarily and heavily punished by fines and expulsion, that the illicit trade was effectually suppressed by Colonel Mackinnon, the Commandant of British Kaffraria; and the consequence was, that drunkenness, disease, crime, and insubordination were unknown; and yet that army was frequently placed in the very position that the advocates for the issue of spirits would have said required a dram.

"Small as the amount of sickness and mortality was in the Crimea, during the winter 1855-56, they would have been reduced one-half, I am quite sure, could the rule that was observed in Kaffirland have been enforced there."

In the same Kaffir war (1852), a march was made by 200 men from Graham's Town to Bloemfontein and back; 1000 miles were covered in seventy-one days, or at the rate of nearly 15 miles daily; the men were almost naked, were exposed to great variations of temperature (excessive heat during day; while at night water froze in a bell-tent with twenty-one men sleeping in it), and got as rations only biscuit, meat 1½ ℔, and what game they could kill. For drink they had nothing but water. Yet this rapid and laborious march was not only performed easily, but the men were "more healthy than they had ever been before; and after the first few days ceased to care about spirits. No man was sick till the end of the march, when two men got dysentery, and these were the only two who had the chance of getting any liquor."

In the last New Zealand war, Dr Neill (Staff Assistant-Surgeon) found that the troops marched better, even when exposed to wet and cold, when no spirits were issued, than when there was a spirit ration.

In the expedition to the Red River, under Sir Garnet Wolseley, no alcoholic liquid was issued. Two accounts of this remarkable march have been published—one by Captain Huyshe,[1] and the other by an officer who wrote an interesting account of the march in *Blackwood's Magazine*.[2] Captain Huyshe says:—

"Although it was an unheard-of thing to send off an expedition into a wilderness for five months without any spirits, still as the backwoodsman was able to do hard work without spirits, it was rightly thought that the British soldiers could do the same. The men were allowed a large daily ration of tea, 1 oz. per man—practically as much as they could drink; and, as I am now on this subject of bohea *versus* grog, I may as well state that the experiment was most successful. The men of no previous expedition have ever been called upon to perform harder or more continuous labour for over four months. . . . They were always cheery, and worked with a zealous will that could not be surpassed. This expedition would have been a bright era in our military annals had it no other result than that of proving the fallacy hitherto believed in of the necessity of providing our men when in the field with intoxicating liquors."

The writer in *Blackwood's Magazine* says:—

"The men were pictures of good health and soldier-like condition whilst stationed at Prince Arthur's Landing and the other larger camps. The men had fresh meat, bread, and potatoes every day. No spirits were allowed throughout the journey to Fort Garry, but all ranks had daily a large ration of tea. This was one of the very few military expeditions ever undertaken by English troops where intoxicating liquors formed no part of the daily ration. It was an experiment based upon the practice common in Canada, where the lumbermen, who spend the whole winter in the backwoods, employed upon the hardest labour, and exposed to a freezing temperature, are allowed no spirits, but have an unlimited quantity of tea. Our old-fashioned generals accept, without any attempt to question its truth, the traditional theory of rum being essential to keep the British

[1] *Journal, United Service Institution*, 1871, vol. xv. p. 74.
[2] January 1871, p. 64.

soldier in health and humour. Let us hope that the experience we have acquired during the Red River expedition may have buried for ever this old-fogyish superstition. Never have the soldiers of any nation been called upon to perform more unceasingly hard work, and it may be confidently asserted without dread of contradiction, that no men have ever been more cheerful or better behaved in every respect. No spirit ration means no crime; and even the doctors, who anticipated serious illness from the absence of liquor, will allow that no troops have ever been healthier than they were from the beginning to the end of the operation. With the exception of slight cases of diarrhœa, arising from change of diet, it may be said that sickness was unknown amongst us."

Sir Garnet Wolseley[1] (now Lord Wolseley), who commanded in this remarkable expedition, speaks very strongly against the rum ration, and says that, by substituting tea for rum, the health and efficiency of the men are increased, "their discipline will improve as their moral tone is raised, engendering a manly cheerfulness that spirit-drinking armies know nothing of."

In the Ashanti campaign of 1874 observations were carefully recorded by several officers.[2] The conclusions arrived at were—1. That abstinence did not render those who abstained more sickly as a whole or more liable to malarious fever; nor did it interfere with their powers of marching. 2. The issue of a ration of rum seemed to do good when given at the end of the day before going to rest. 3. That the quantity ($2\frac{1}{2}$ oz.) was amply sufficient. On the whole, the necessity for the ration was by no means proved, although some officers returned rather shaken in their previous belief that alcohol was absolutely unnecessary in a military expedition.

In sieges, which are perhaps more trying to men than campaigning in the open field, the advantage of temperance has, on two occasions, been very marked. In the great siege of Gibraltar, Sir George Elliot, who was a teetotaller, enforced the most rigid temperance, and the long and arduous blockade was passed through with remarkably little sickness. At the siege of Jellalabad, in Affghanistan, the "illustrious garrison" were quite destitute of all alcoholic liquors; and, to the astonishment of the officers, the Europeans never had been so healthy, cheerful, martial, and enduring, and free from crime. During the Indian mutiny many regiments were debarred from spirits for a long time, and were much healthier than when they got them.

In fact, it may be confidently asserted that in war, spirits especially, and indeed all alcoholic liquors, are better avoided; and the phrase of an American army surgeon in the civil war, who noticed how great was the improvement when spirit prohibition was enforced, is fully justified by our own experience—"The curse of an army is intoxicating liquors; the spirit ration is the source of all this mischief."

When debarred from spirits and fermented liquids, men are not only better behaved, but are far more cheerful, are less irritable, and endure better the hardships and perils of war. The courage and endurance of a drunkard are always lessened; but in a degree far short of drunkenness, spirits lower, while temperance raises, the boldness and cheerfulness of spirit which a true soldier should possess.[3]

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[1] *Soldiers' Pocket Book*, 2nd edition, p. 172.

[2] *On the Issue of a Spirit Ration during the Ashanti Campaign of* 1874 (Parkes).

[3] The custom of giving rations of spirits to soldiers and sailors (even now not altogether discontinued) was one of those incredible mistakes which are only made worse by the explanation that it was done to please the men and cover neglect in other ways. If any one wishes to see what our army was in former days, and how dreadful military regulations made men drunkards in spite of themselves, they may refer to an old Peninsular surgeon's (William Fergusson's) *Notes and Recollections of a Professional Life* (1846). "During the last war" (he says, p. 74) "our sailors and soldiers appeared to live for the purpose of getting drunk; with them it seemed to be the chief article of their creed—the chief end of

Looking back to this evidence, it may be asked, Are there any circumstances of the soldier's life in which the issue of spirits is advisable, and, if the question at any time lies between the issue of spirits and total abstinence, which is the best?

There seems but one answer. If spirits neither give strength to the body, nor sustain it against disease—are not protective against cold and wet, and aggravate rather than mitigate the effects of heat—if their use even in moderation increase crime, injure discipline, and impair hope and cheerfulness—if the severest trials of war have been not merely borne, but most easily borne without them—if there is no evidence that they are protective against malaria or other diseases—then the medical officer will not be justified in sanctioning their issue under any circumstances.

The terrible system which in the East and West Indies made men drunkards in spite of themselves, and which by the issue of the morning dram did more than anything else to shatter the constitutions of the young soldiers, is now becoming a thing of the past. But the soldier is still permitted to get spirits too easily, and is too ignorant of their fatal influence on his health. Still the British army bears the unhappy character of the most intemperate army in Europe, and it is certain that its moments of misconduct and misfortune have been too frequently caused by the unrestrainable passion for drink. Remembering all these things, and how certainly it has been proved that drunkenness increases the spread of syphilis, it is not too much to say that the repression of this vice should be one of the chief duties of every officer in the army. Moderation should be encouraged by precept and example; wholesome beer and light wine should be invariably substituted for spirits, and, if these cannot be procured, it may safely be said that the use of tea, coffee, or simple water is preferable to spirits under all circumstances of the soldier's life.

Resistance to Disease.—Malaria.—There are instances for and against the view that spirits are useful against malaria. On both sides the evidence is defective; but there are so many cases in which persons have been attacked with malarious disease who took spirits, that it is impossible to

life. . . . . 'Grog, grog,' was still the cry; I have seen it, as it were, forced down the throats of the innocent negro boy and the uncorrupted young recruit. We seemed to believe that the term *aqua vitæ* was its true designation. Every one was to have it, no matter what the age, the colour, the country, or the breeding. Our Portuguese allies in the Peninsula were the soberest of mankind. They liked their own weak country wine to dilute their food, but that would not do for us. We actually sent for the rum of the West Indies and gave it them; and at the battle of Busaco I saw a party of Portuguese artillery, as soon as the rum ration was served, as if they had been possessed by a devil (and they actually were possessed by a devil in the shape of alcohol), draw their swords and fight with one another when actually under the fire of the enemy" (p. 85).

He cites numerous most lamentable facts, and well concludes that "our canteen system will in after times be viewed with horror and astonishment, at its folly, corruption, and wickedness."

These opinions are not recalled without a motive. There is too much reason to fear that many officers still believe that soldiers must have spirits. Fergusson says that "the exceeding vulgarity of the prejudice that ardent spirits impart strength and vigour to the human frame is disgraceful to educated men"; and yet this belief is still actually held by persons in authority. Although in the army drinking is the great source of all crime and insubordination; although even within late years we have had one if not more instances that, even during an assault, men will sacrifice anything, even their honour, to obtain spirits; although the best officers know that this is the one point on which they cannot depend on their men, far too little has been done to make our army temperate. This does not mean that nothing has been done; on the contrary, in this, as in all things, progress has been made, but the measures are not sufficient to control an evil so gigantic. It is the same thing in civil life; there is no question that more disease is, directly and indirectly, produced by drunkenness than by any other cause, and that the moral as well as the physical evils proceeding from it are beyond all reckoning; and yet the attempts of the legislature to set some bounds to intemperance have been and are opposed with a bitterness which could only be justified if the degradation and not the improvement of mankind was desired.

consider the preventive powers great, even if they exist at all. On the other hand, when teetotallers have escaped malaria (as in the instance recorded by Drake),[1] there have been other circumstances, such as more abundant food and better lodging, which will explain their exemption. The probability is, that the reception and action of malaria are not influenced by the presence or absence of alcohol in the blood unless the amount of alcohol is so great as to lessen the amount of food taken.

Yellow Fever.—It is a general opinion in New Orleans and Mobile that the victims of yellow fever are chiefly those who drink freely (Drake). The old West Indian experience is to the same effect.

Cholera.—Intemperance, *per se*, has no influence, and teetotalism does not guard against cholera. When a regiment is attacked with cholera, and the men take to drinking, a number of pseudo-cases come into hospital of vomiting and cramps, which are often returned as cholera, but they seldom if ever pass into true cholera.

Dysentery.—It has been supposed, from some statistics for 1847, published in the *Fort George Gazette*, that teetotallers were more subject to dysentery, but the error was committed of not estimating sufficiently the influence of a particular station (Secunderabad), where it so happened a number of teetotallers were stationed during an outbreak of dysentery. The conditions of the station were to blame, not the habits of the men.

In none of the conditions now enumerated is there any evidence that alcohol is desirable.

Conclusion as to the Use of Alcohol.

The facts now stated make it difficult to avoid the conclusion that the dietetic value of alcohol has been much over-rated. It does not appear possible at present to condemn alcohol altogether as an article of diet in health, or to prove that it is invariably hurtful, as some have attempted to do. It produces effects which are often useful in disease and sometimes desirable in health, but in health it is certainly not a necessity, and many persons are much better without it. As now used by mankind (at least in our own, and in many other countries), it is infinitely more powerful for evil than for good; and though it can hardly be imagined that its dietetic use will cease in our time, yet a clearer view of its effects must surely lead to a lessening of the excessive use which now prevails. As a matter of public health, it is most important that the medical profession should throw its great influence into the scale of moderation; should explain the limit of the useful power, and show how easily the line is passed which carries us from the region of safety into danger, when alcohol is taken as a common article of food.[2]

Dietetic Use of Alcoholic Beverages.

In the previous remarks, the effect of alcohol only has been discussed, but beer and wine contain other substances besides alcohol.

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[1] *On the Interior Valley of North America.*

[2] A great evil is growing up in India, which now could be checked, but which we shall be powerless to meet in a few years. The Hindoos, formerly the most temperate of races, are rapidly becoming addicted to drink. This is said to be partly owing to the regulations of the Government permitting, and even encouraging the sale of spirits, although the alcoholic liquors form no part of the ordinary food of the people, and therefore their prohibition is not difficult; and partly from the bad example of the Europeans in India, who, as the dominant race, are impressing more and more the nations whom they control. It seems a matter which our statesmen may well look into, for it involves the happiness of many nations.

In wine there are some albuminous substances, much sugar (in some wines), and other carbo-hydrates, and abundant salts. Whether it is that the amount of alcohol is small, or whether the alcohol be itself, in some way, different from that prepared by distillation,[1] or whether the co-existence of carbo-hydrates and of salts modifies its action, certain it is that the moderate use of wine, which is not too rich in alcohol, does not seem to lead to those profound alterations of the molecular constitution of organs which follow the use of spirits, even when not taken largely. Considering the large amounts of vegetable salts which most wines contain, it may reasonably be supposed that they play no unimportant part in giving dietetic value to wine. Indeed, it is quite certain that, in one point of view, they are most valuable; they are highly anti-scorbutic, and the arguments of Lind and Gillespie, for the introduction of red wine into the royal navy instead of spirits, have been completely justified in our own time by both French and English experience. It is now certain that with the same diet, but giving in one case red wine, in another rum, the persons on the latter system will become scorbutic long before those who take the wine. This is a most important fact, and in a campaign the issue of red wines should never be omitted. The ethers may also be important if, as indicated by Bernard, and recently pointed out by Sir B. W. Forster,[2] they excite the flow of the pancreatic secretion, and thereby promote the absorption of fat.

In beer there appear to be four ingredients of importance, viz., the extractive matters and sugar, the bitter matters, the free acids, and the alcohol. The first, no doubt, are carbo-hydrates, and play the same part in the system as starch and sugar, appropriating the oxygen, and saving fat and albuminoids from destruction. Hence, one cause of the tendency of persons who drink much beer to get fat. The bitter matters are supposed to be stomachic and tonic; though it may be questioned whether we have not gone too far in this direction, as many of the highest priced beers contain now little else than alcohol and bitter extract. The action of the free acids is not known; but their amount is not inconsiderable; and they are mostly of the kind which form carbonates in the system, and which seem to play so useful a part. The salts, especially potassium and magnesium phosphates, are in large amount.

It is evident that in beer we have a beverage which can answer several purposes, viz., can give a supply of carbo-hydrates, of acid, of important salts, and of a bitter tonic (if such be needed) independent of its alcohol, but whether it is not a very expensive way of giving these substances is a question.

In moderation, it is no doubt well adapted to aid digestion, and to lessen to some extent the elimination of fat. It may be inferred that beer will cause an increase of weight of the body, by increasing the amount of food taken in, and by slightly lessening metamorphosis; and general experience confirms those inferences. When taken in excess, it seems to give rise to gouty affections more readily even than wine.

In spirits, alcohol is the main ingredient, chiefly in the form of ethyl-alcohol, though there are small amounts of propyl-, butyl-, and in some cases amyl-alcohols. In addition, there are sometimes small quantities of ether; and, in some cases, essential oils (as apparently in absinthe, and in one kind of Cape brandy), which have a powerful action on the nerves.

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[1] Thudichum and Dupré could not, however, trace any difference between the alcohol in wines and that derived from other sources.

[2] *Brit. Med. Journal*, Nov. 1868.

But spirits are, for the most part, merely flavoured alcohol, and do not contain the ingredients which give dietetic value to wine and beer. They are also more dangerous, because it is so easy to take them undiluted, and thus to increase the chance of damaging the structure and nutrition of the albuminous structures with which they come first in contact. There is every reason, therefore, to discourage the use of spirits, and to let beer and wines, with moderate alcoholic power, take their place.

SECTION II.

NON-ALCOHOLIC BEVERAGES.

Sub-Section I.—Coffee.

Unroasted coffee contains much cellulose (34 per cent.), fat (10 to 13 per cent.), sugar and dextrin, and vegetable acid (15·5), and legumin (10 per cent.). There is also a solid acid, aromatic oil in small quantities, caffein, and ash, the chief ingredients of which are potash and phosphoric acid. The total amount of caffein (free and combined), according to Payen, is about 1·736 per cent.; but this is more than other observers have found. In roasted coffee berries the average of Boutron and Robiquet's analyses gives 0·238 per cent. of caffein. Aubert[1] has given the amount as from 0·709 to 0·849 per cent., and Witte makes it 0·666 per cent.; Graham, Stenhouse, and Campbell state it as 0·87 per cent. It may be assumed to be 0·75 per cent. on an average. Aubert found that roasting coffee to any extent caused very little loss of caffein. The caffein is extracted easily by benzol or by chloroform.[2]

When coffee is roasted it swells, but becomes lighter (15 to even 25 per cent., if the coffee is dark roasted). The sugar is changed into caramel, the peculiar aroma is developed, the union between the caffein and the caffeo-tannic acid is broken up; several gases are formed, viz., carbon dioxide (in greatest amount), carbon monoxide, and nitrogen. It is owing to these gases that the roasted coffee swells so much.[3] In the infusion almost all the caffein is found, according to Aubert, while others say about one-half is lost. Aubert has found that in a cup of coffee made with 16·66 grammes, or 0·587 ounce avoirdupois (1 Prussian loth), there are from 0·1 to 0·12 gramme (= 1·5 to 1·9 grains of caffein). In a cup of tea made from 5 to 6 grammes (= 77 to 92 grains) of tea, about the same amount of caffein is contained.

As an article of diet, coffee stimulates the nervous system, and in large doses produces tremors. Caffein given to animals augments reflex action, and may produce tetanus, or peculiar stiffness of muscles. It increases the frequency of the pulse in men, and removes the sensation of commencing fatigue during exercise. It has been said (J. Lehmann and others) to lessen

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[1] *Archiv für die ges. Phys.*, Band v. p. 589.

[2] Caffein and thein are the same substance. Theobromin belongs to the same series, and has apparently identical effects. In the leaves of the Paraguay tea (*Ilex paraguayensis*, the tea is called Maté in Paraguay), which are used to make tea in the Argentine Confederation and throughout the southern part of Brazil, there is also an alkaloid identical with thein. In dietetic properties, Paraguay tea is thought to stand between coffee and Chinese tea, but to be more like coffee. The alkaloid in guarana is also thein, according to Stenhouse.

[3] Coulier, *Recueil de Mémoires de Méd. Mil.*, Juin 1864, p. 508.

the amount of urea and phosphoric acid, but this is doubtful.[1] It appears, however, to increase the urinary water. The pulmonary carbon dioxide is said to be increased (E. Smith). It increases the action of the skin.

In animals (frogs, dogs, and rabbits) caffein produces the following effects, as determined by Aubert and others:—Increased reflex action; a peculiar stiffness of the muscles, sometimes tetanus; no lessening of nervous excitability; an invariable increase in pulse-frequency and a lessening of the blood-pressure (in dogs). This effect on the circulation is peculiar and complex. Aubert is convinced that the work of the heart is less, in spite of the increased beats; there is not time for perfect contraction, and this lessened

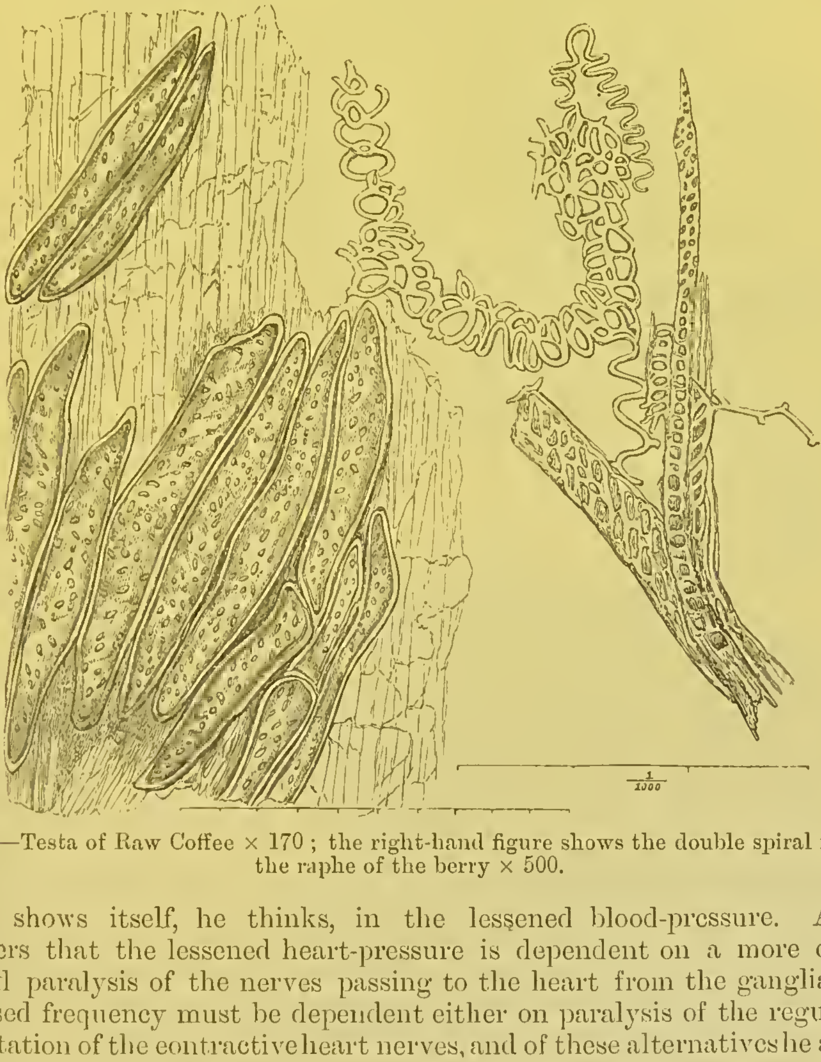

Fig. 79.—Testa of Raw Coffee × 170; the right-hand figure shows the double spiral fibres in the raphe of the berry × 500.

power shows itself, he thinks, in the lessened blood-pressure. Aubert considers that the lessened heart-pressure is dependent on a more or less marked paralysis of the nerves passing to the heart from the ganglia; the increased frequency must be dependent either on paralysis of the regulating or excitation of the contractive heart nerves, and of these alternatives he adopts the latter. He thinks it uncertain if coffee owes its dietetic value to the caffein or not.

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[1] While Hoppe found a decrease in dogs, Voit found no alteration of urea; and some very careful experiments made by Dr Squarey, of University College, do not confirm Lehmann's observations on men, so far as the urea is concerned. Dr Squarey's experiments are far more complete than those of Lehmann; the urea was not affected even by very large quantities of coffee. It would be interesting to examine the urine again after the use of the *Erythroxylon coca*. The late work of M. Moreno, of Maiz (Paris, 1868), confirms the previous statements of the removal of the sensation of hunger by this substance. The cold infusion increases, he affirms, the arterial tension. Dr Edmonstone Charles has lately called attention to its power of preventing thirst.

Coffee is a most important article of diet for soldiers,[1] as not only is it invigorating, without producing subsequent collapse, but the hot infusion is almost equally serviceable against both cold and heat; in the one case, the warmth of the infusion, in the other, the action on the skin, being useful, while in both cases the nervous stimulation is very desirable. Dr Hooker tells us that in the Antarctic expedition the men all preferred coffee to spirits, and this was the case in the Schleswig-Holstein war of 1849.

The experience of Algeria and India (where coffee is coming more and more into use) proves its use in hot climates.

It has been asserted to be protective against malaria. The evidence is not strong, but still is sufficient to authorise its use in malarious districts.

Making of Coffee.—Roasted and ground coffee must be served out to troops, as the delicate operation of roasting can never be performed by soldiers. Exposed to the air the roasted and ground coffee loses its aroma in from two to four months; but if packed in tins it will keep it for several months. The tins should not be too large, so that no more than necessary may be exposed to the air. It has been said that the tin is acted upon, but this does not appear to be the case for some time. The amount should be at least $\frac{6}{10}$ths of an ounce for each person per meal.

Fig. 80.—Raw Coffee-berry; transverse section. × 170.

The coffee must not be boiled, or the aroma is in part dissipated; but, if made with water of 180° or 200°, the coffee only gives up 19 to 25 per cent., whereas it ought to yield 30 to 35 per cent. In order to get the full benefit of the coffee, therefore, after the infusion has been poured off, the grounds should be well boiled in some more water, and the hot decoction poured over fresh coffee, so that it may take up aroma; the coffee thus partially exhausted can be used on the next occasion for boiling.

The infusion of coffee has a specific gravity of about 1008 to 1010; the oil, caffein, sugar, dextrin, and mineral matters are taken up by water.

Choice of Coffee.—This is determined entirely by the aroma and taste of the roasted coffee and of the infusion. If the coffee has been damaged (as by sea-water, when the berries are washed in fresh water and redried) there is always a disagreeable taste even after roasting (Chevallier). The berries give up less than usual to water (12 per cent.).[2]

Adulterations.—The microscope detects adulterations with the greatest facility.

[1] The ration, one ounce, is generally too small, and might advantageously be doubled at least. See experiments recorded in *The Issue of a Spirit Ration* (Parkes), Appendix I. p. 39 *et seq.*

[2] With regard to the choice of the coffee berry some caution must be used. The best coffee, that of Yemen, originally the Abyssinian berry, is a moderately large full berry (according to Palgrave), the inferior sorts being small and shrivelled. In India the same rule does not seem to hold good, and officers of experience have stated that in that country the best coffee is often a shrivelled and uninviting-looking article, whilst the fuller and apparently finer samples are really inferior for use as a beverage.

The structure of the coffee-berry is shown in the drawings. The long cells of the testa (figs. 79 and 81) are very marked. The interior of

Fig. 81.—Roasted Coffee ; the dark cells, containing air, show the spiral fibre.

the berry also presents characters which are quite evident ; an irregular areolar tissue contains light or dark yellow angular masses and oil globules, which are very different from any adulterations. The little corkscrew-like unrolled spiral fibres are chiefly found in the bottom of the raphe. The usual adulterations of coffee are roasted chicory,[1] cereal grains or beans, potatoes, or sugar.

Fig. 82.—Roasted Coffee-berry ; transverse section.

1. *Chicory* is discovered by its smell ; by yielding a darker and denser infusion of a specific gravity of 1018 to 1020 ; and by its microscopic characters. It also sinks at once in water when roasted, whereas coffee floats for a long time, in consequence of the development of gas during roasting, or from the non-absorbent character of the perisperm and hard yellow granules of

[1] Chicory is itself adulterated with roasted barley and wheat grain, acorns, mangold-wurzel, sawdust, and beans and peas.

the cellulose. The microscopic test is the most important, and both the cells and dotted ducts of chicory are quite characteristic; at least nothing like them exists in coffee.[1] The percentage of ash has been suggested as a means of detection. Coffee yields about 4 per cent., of which four-fifths are soluble in water; chicory yields about 5 per cent., of which only one-third is soluble.

Chicory contains a notable amount of sugar (12 to 14 per cent.), whereas coffee has never more than 1 per cent. Wanklyn has proposed to make this a basis of detection, using the standard copper solution.

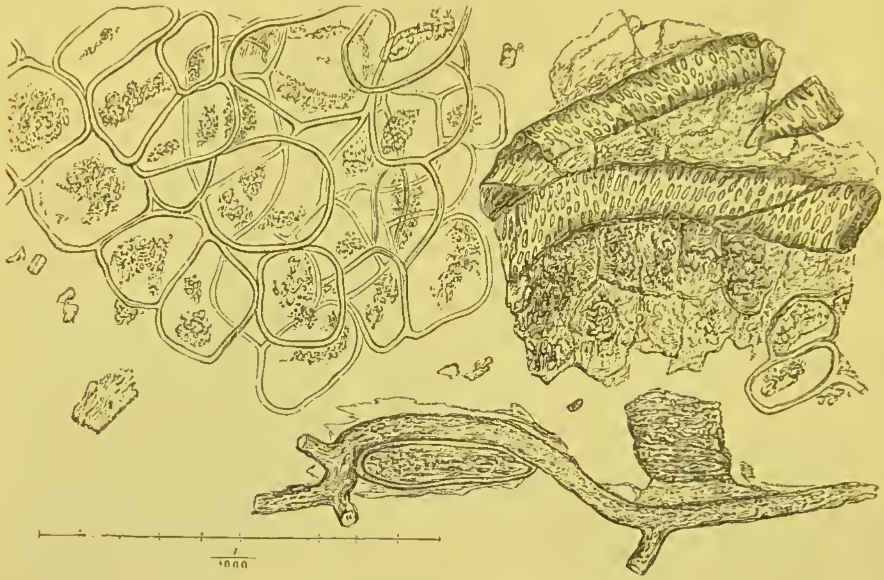

Fig. 83.—Chicory Root; cells and dotted ducts.

2. Roasted *corn* or *beans* are at once known by the starch grains, which frequently preserve the precise character of wheat or barley or beans. Iodine turns them at once blue. The infusion also gives a blue with iodine.

3. *Potato* starch is also at once detected; there is nothing like it in coffee. *Sago* starch, which is sometimes used, is easily detected.

4. *Sugar* is detected by solution, and by the copper solution which it reduces, as the kind of sugar is almost always glucose. If caramel or burnt sugar be present, make an infusion, evaporate, dry, and taste: if the extract be brittle, dark coloured, and bitter to the taste, caramel has been added (Hassall).

5. Pereira[2] has given a long list of adulterations of chicory, and Hassall has also detected mixture with mangold-wurzel, parsnip, carrot, acorn, and sawdust. The cells of mangold-wurzel are like chicory, but much larger; those of carrot and parsnip are something like chicory, but contain starch cells; the starch grains of the acorn are round or oval, with a deep culvert depression, or hilum. The infusion of chicory is not turned blue by iodine; when incinerated the ash of chicory should not be less than 5 per cent.

The use of coffee is steadily decreasing in this country, due largely to the amount of adulteration which existing legislation seems rather to foster than repress.

[1] Various vegetable substances are now permitted to be sold as substitutes for coffee, provided they are properly labelled and made up in ¼ lb packets.

[2] *Materia Medica*, vol. ii. p. 1578 (1863).

SUB-SECTION II.—TEA.

The chief kinds of black tea are Souchong, Congou, Oolong, and Pekoe. Bohea is not now found in the market. The chief green teas are Hyson, Hyson-stem, Twankay, Caper, and Gunpowder.

Dry tea contains about 1·8 per cent. of thein, 2·6 of albumen, 9·7 of dextrin, 22 of cellulose, 15 of tannin, 20 of extractives, 5·4 of ash, as well as other matters, such as oil, wax, and resin.

In some good teas the amount of thein is much greater. Péligot found as much as 6·21 per cent. in dry tea. The thein is combined with tannic acid.

Black tea contains from 6 to 10 per cent. of water—more often the latter quantity; green tea about 8 per cent.

The ash[1] consists principally of potash, soda, magnesia, phosphoric acid, chlorine, carbonic acid, iron, silica, and traces of manganese.

There is rather more tannic acid, and more thein and æthcrial oil, in green than black tea, and less cellulose: otherwise the composition is much the same (Mulder).

Black tea yields to boiling water, . .		29–45 per cent.
	As a mean, .	38 ,,
Green[2] ,, ,, . .		40–48 ,,
	As a mean, .	43 ,,

About $\frac{9}{10}$ths of the soluble matters are taken up by the first infusion with hot water.[3]

If water contain much lime or iron it will not make good tea; in each case the water should be well boiled with a little carbonate of soda for 15 or 20 minutes, and then poured on the leaves.

In the infusion are found dextrin, glucose, tannin, and thein. About 47 per cent. of the nitrogenous substances pass into the infusion, and 53 per cent. remain undissolved. If soda is added, a still greater amount is given to water.

The green tea (now little sold) is either natural, or coloured (faced) with indigo, Prussian blue, clay, carbonate and acetate of copper, curcuma, gypsum, and chalk.

Scraping the tea-leaves and microscopic examination at once detect the shining blue particles of indigo and Prussian blue; and the addition of an acid indicates which is indigo. Copper is at once detected by solution in an acid and addition of ammonia. Letheby stated that black lead is used to give a bloom to black teas.[4]

As an Article of Diet.—Tea seems to have a decidedly stimulative and restorative action on the nervous system, which is perhaps aided by the warmth of the infusion. No depression follows this. The pulse is a little quickened. The amount of pulmonary carbon dioxide is, according to E. Smith, increased.[5] The action of the skin is increased, that of the bowels

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[1] The Society of Public Analysts have adopted 8 per cent. of ash as the maximum of perfectly dry tea. The amount in ordinary tea is about 5 to 6 per cent., of which about 3 per cent. is soluble. The ash of *spent* tea is only about 3 per cent., of which 0·5 is soluble.

[2] There appears now to be very little green tea in the market, since it has been decided that "facing" is an adulteration.

[3] The Society of Public Analysts have adopted 30 per cent. as the minimum extract in genuine tea; Wanklyn takes 32, and certainly good genuine tea yields this at least.

[4] The brick tea of the Tartars consists of old tea leaves, mixed with the leaves and stems of *Rhamnus theëzans*, *Rhododendron*, *Chrysanthemum*, *Rosa canina*, and other plants, mixed with ox's or sheep's blood. It is much used to purify water.

[5] *Phil. Transactions*, 1859.

lessened. The kidney excretion is little affected, perhaps the urea is a little lessened, but this is uncertain.[1]

As an article of diet for soldiers, tea is most useful. The hot infusion, like that of coffee, is potent both against heat and cold; is most useful in great fatigue, especially in hot climates (Ranald Martin); and also has a great purifying effect on water. Tea is so light, is so easily carried, and the infusion is so readily made, that it should form the drink *par excellence* of the soldier on service. There is also a belief that it lessens the susceptibility to malaria, but the evidence on this point is imperfect.

Choice of Tea.—The tea should not be too much broken up, or mixed up with dirt. Spread out, the leaves should not be all large, thick, dark, and old, but some should be small and young. There will always be in the best tea a good deal of stalk and some remains of the flower. In old tea much of the ætherial oil evaporates, and the aroma is less marked.

The infusion should be fragrant to smell, not harsh and bitter to taste, and not too dark. The buyers of tea seem especially to depend on the smell and taste of the infusion.

Structure of the Tea Leaf.—The border is serrated nearly but not quite to the stalk; the primary veins run out from the midrib nearly to the border, and then turn in, so that a distinct space is left between them and the border. The leaf may vary in point of size and shape, being sometimes broader, and sometimes long and narrow. The appearance under the microscope of the upper and under surfaces is seen in the drawing. The border and the primary venation distinguish it from all leaves.[2] The leaves which it is said have been mixed with or substituted for tea in this country are the willow, sloe, oak, Valonia oak, plane, beech, elm, poplar, hawthorn, and chestnut; and in China *Chloranthus inconspicuus* and *Camellia Sasanqua* are said to be used. Of these the willow and the sloe are the only leaves which at all resemble tea-leaves. The willow is more irregularly, and the sloe is much less perfectly and uniformly serrated.

To examine the leaves, make an infusion, and then spread out a number of leaves; if a leaf be placed on a glass slide, and covered with a thin glass, and then held up to the light, the border and venation can usually be well seen.

The leaves of the Valonia, if used, are at once detected by acicular crystals being found under the microscope.

Sometimes exhausted tea-leaves are mixed with catechu or with a coarse powder of a reddish-brown colour, consisting chiefly of powdered catechu, and called "La Veno Beno." Gum and starch are added, the leaves being steeped in a strong solution of gum, which, in drying, contracts them. The want of aroma, and the collection at the bottom of the infusion of powdered catechu, or the detection of particles of catechu, will at once indicate this falsification, which is, however, very uncommon. Sand and magnetic oxide

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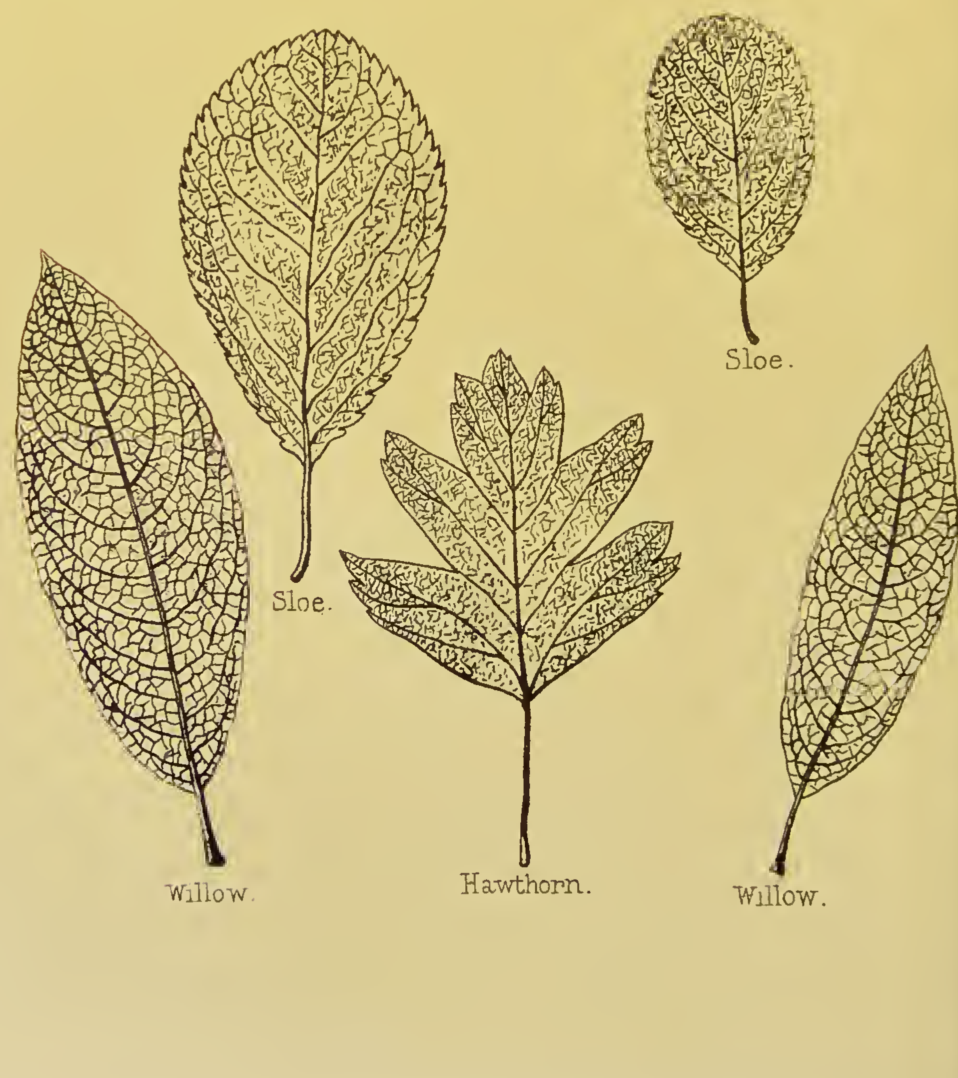
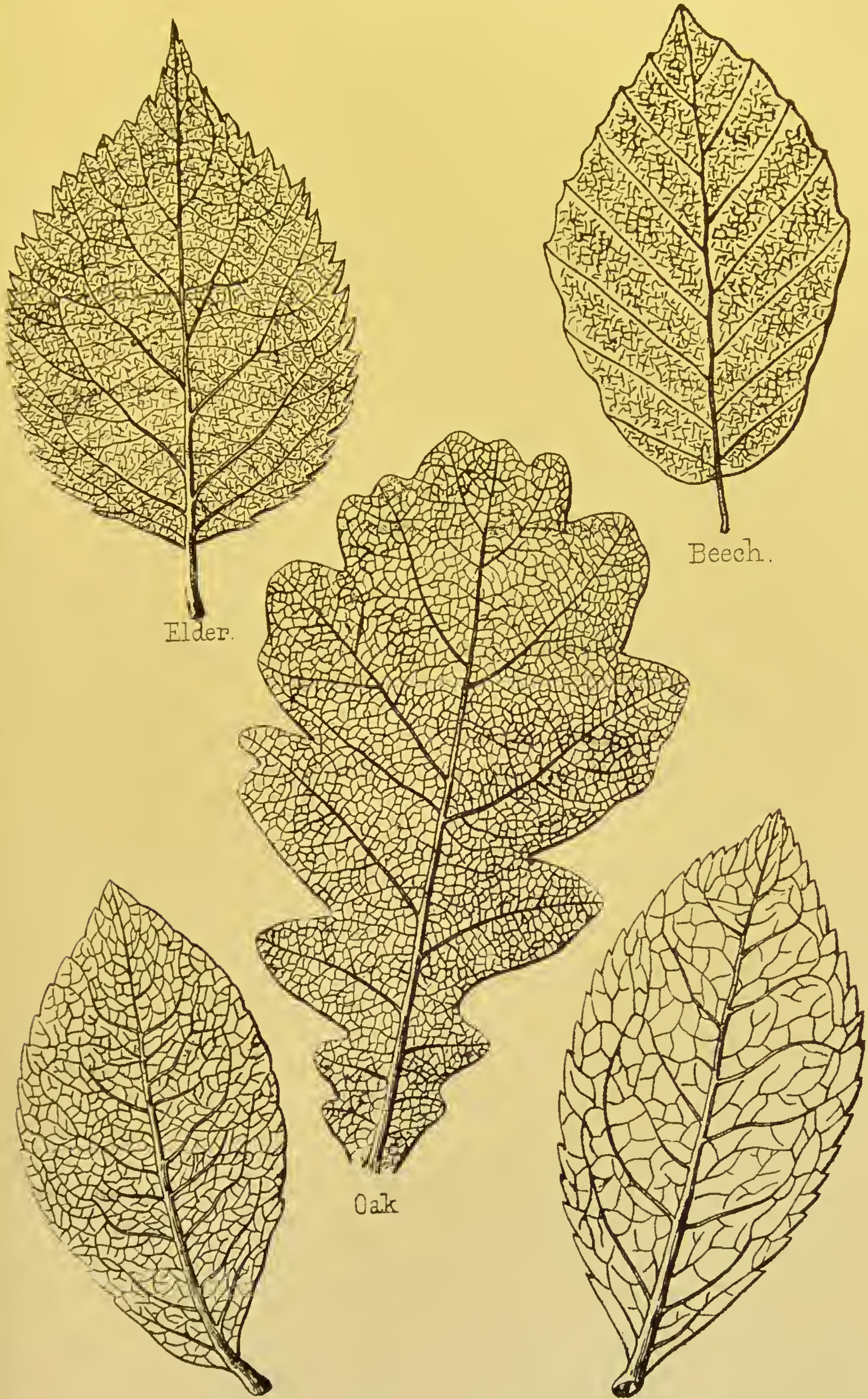
[1] The evidence with respect to the urine is very contradictory; but, on the whole, the action seems to be inconsiderable. Dr Edward Smith considers that "tea promotes all vital actions, and increases the action of the skin." It is, perhaps, impossible at present to express its action in so succinct a form.

[2] The structure of the serrature is rather peculiar, showing an apparently abortive leaf-bud just within the point. This organ can be seen distinctly with an ordinary pocket lens, and consists of a cylindrical basal portion and a more or less cone-shaped apical part. From the reticulated body of the venation a distinct little funiculus may be traced into each of the minute bud-like bodies which are situated just *within* the tip of the serrature. This latter particular is of importance, for, as might be expected, somewhat similar appendages may be found in other serrated leaves, but in all cases hitherto examined, they occur *at* instead of *within* the point of the serratures. No notice appears to have been taken of this fact by structural botanists; but Dr Macdonald, who first called attention to it, refers the bodies themselves to the category of marginal buds.

Leaves and stalks of best Tea brought from China (1861) by private hand natural size.
Generally in Commercial Tea the leaves are much larger & thicker, & often are cut transverly into two or three parts Some stalks & remains of Flowers are found in all Tea even the best.





Camellia Sasanqua.   Chloranthus Inconspicuus.

LEAVES USED IN THE ADULTERATION OF TEA

The Sloe, Willow, Oak, Beech, Elder, and Hawthorn have been nature-printed & then Lithographed. The Drawings of the Chloranthus Inconspicuus and the Camellia Sasanqua, which are said to be used by the Chinese are copied from Hassall. The leaves of the Elm. Poplar Plane are said to be sometimes used in England. Falsification with any kind of leaf is however now decidedly uncommon in this Country.

M&N. Hanhart imp.

of iron are added by the Chinese. At first the latter was mistaken for iron filings, and when it was proved to be really magnetic oxide it was suggested that it came accidentally from the soil where the tea was cultivated. Hassall, however, gives good reasons for its being a wilful addition.[1]

Extraction of Thein.

Occasionally it may be desired to determine the quantity of thein. Take 10 grammes of tea, exhaust with boiling water, and add solution of subacetate

Fig. 84.—Dried Black Tea Leaf.

of lead; filter; pass hydrosulphuric acid through to get rid of excess of lead; filter; evaporate to small bulk, and add a little ammonia; add more water, decolorise with animal charcoal, and evaporate slowly to small bulk. White feathery crystals of thein form, which should be collected on filtering paper, dried at a very low heat, and weighed.

Determination of Tannin.

Make an infusion and add solution of gelatine; collect precipitate, dry and weigh—100 = 40 of tannin (Marcet).

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[1] Minute quantities have been found in two instances in tea supplied to Netley Hospital; in one the ash was 6·055 per cent., in the other 6·220. Hassall states that he has never found it except in tea that has been undoubtedly adulterated and yielded a very much greater amount of ash.

Examination of Tea.

Judge of the aroma of the dry tea and infusion; taste infusion; spread out leaves and see their characters; collect anything like mineral powder, and examine under microscope. The microscope will also show if the tea has deteriorated by keeping; sometimes *acari*, *fungi*, and *bacteria* may be found.

To make the infusion, take 10 grammes of tea, and infuse in 500 c.c. of *boiling* distilled or rain water.[1] Let it stand five or six minutes before smelling and tasting it. Exhaust the leaves by boiling with successive portions of water, until no colour is given up to the water. Measure the total amount of the infusion; take 100 c.c. and dry it in a water-bath,[2] and weigh. Calculate out the percentage.

Example.—The total quantity of the infusion from 10 grammes of tea was 1890 c.c.; 100 c.c. taken and dried yielded 0·21 of extract; then $\frac{1890}{100} \times 0{\cdot}21 = 3{\cdot}969$ of extract in 10 grammes; this multiplied by $10 = 39{\cdot}69$ per cent.

The exhausted leaves may also be dried and weighed, the loss representing the amount of extract, which ought to correspond with the amount obtained directly.

The ash should also be determined; 5 or 10 grammes are to be incinerated; the ash is generally grey, sometimes slightly greenish. Any excess above 6 per cent. is suspicious; if above 8 per cent. on the *perfectly dry tea*, adulteration is certain. About one-half of the ash is soluble in water; the solution is often (but not always) pink, from the presence of manganese. The amount and character of the ash form good means of detecting the use of exhausted leaves.

The acidity of the infusion, and the amount of tannin and thein may also be determined; as also the chlorine, alkalinity, and iron of the ash. The best tests of the *quality* of the tea are the aroma and the physical characters.

Sub-Section III.—Cocoa.

Composition.—Although the theobromin of cocoa closely resembles thein and caffein, the composition of cocoa removes it widely from tea and coffee. The quantity of fat is large; it varies even in the same sort of cocoa, but is usually from 45 to 49 per cent.[3] The theobromin is 1·2 to 1·5 per cent.; the proteid substances 13 to 18 per cent. The ash contains a large quantity of phosphate of potassium.

As an Article of Diet.—The large quantity of fat and albuminoid substance makes it a very nourishing article of diet; and it is therefore useful in weak states of the system, and for healthy men under circumstances of great exertion. It has been even compared to milk. In South America cocoa and maize cakes are used by travellers; and the large amount of agreeable nourishment in small bulk enables several days' supplies to be easily carried (Humboldt).

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[1] The dealers usually take as much tea as is equal in weight to a new sixpence for the infusion. This is equal to about 3 grammes; it is dissolved in a cupful of water, about 5 ounces or 140 c.c.

[2] Mr Wanklyn suggests a simple form of water-bath,—an ordinary tin oil-can about three-parts full of water; this is boiled over a lamp, and the dish with infusion to be dried held over the narrow mouth in the ring of a retort stand. The drying is soon completed in the steam.

[3] The Society of Public Analysts have adopted 20 per cent. of cocoa butter as the minimum admissible.

By roasting, the starch is changed into dextrin; the amount of margaric acid increases, and an empyreumatic substance is formed.

The changes depend on the amount of roasting; the lighter-coloured nuts contain more unchanged fat, and less aroma; the strongly roasted and dark cocoas have more aroma and bitterness.

Choice and Adulterations.—In commerce, cereal grains, starches, arrowroot, sago, or potato starch and sugar, are very commonly mixed with cocoa; and some of the so-called homœopathic cocoas are rightly named, for the amount of cocoa is very small. Brick-dust and peroxide of iron are sometimes used (Normandy).[1] The structure of the cocoa is very marked.

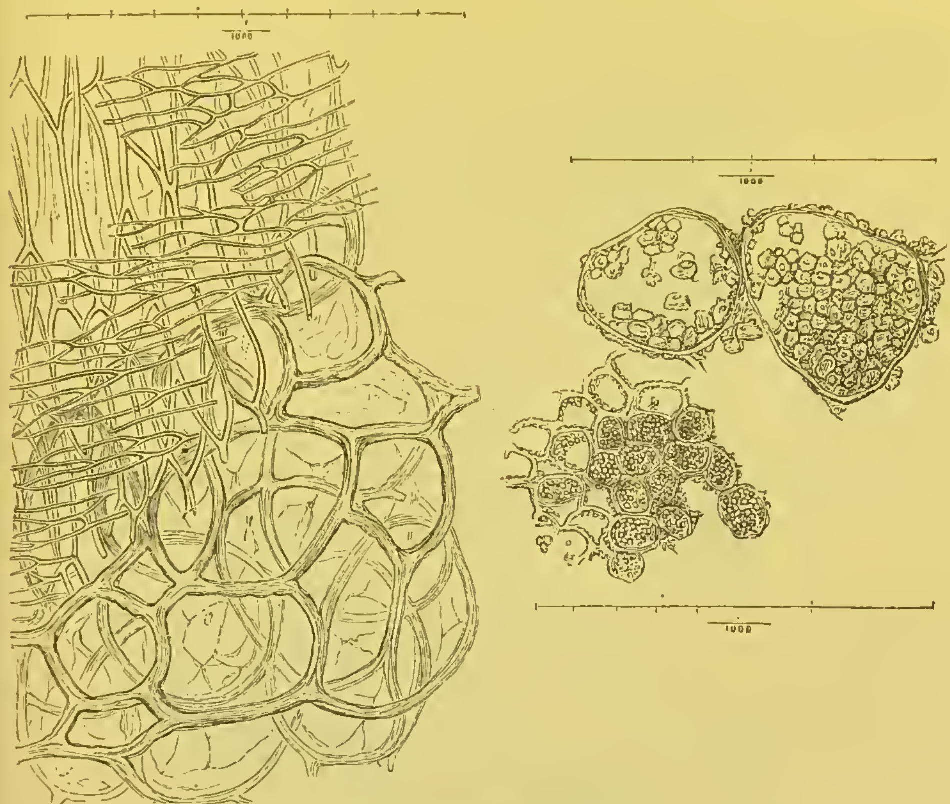

Fig. 85.—Cocoa, outer coat. × 190.

The starch grains of cocoa are small, and embedded usually in the cells. The presence of starch grains of cereals, arrowroot, sago, or other kinds of starch, is at once detected by the microscope. Sugar can be detected by the taste, and by solution. Mineral substances are best detected by incineration, digesting it in an acid and testing for iron, lead, &c.

SECTION III.

CONDIMENTS.

Sub-Section I.—Vinegar.

As an Article of Diet.—Robert Jackson was of opinion that the use of vinegar was too restricted in the army. This opinion he appears to have

[1] Hassall examined 54 samples; 8 were genuine, 43 contained sugar, and 46 starch; 39 out of 68 samples contained earthy colouring matter, as reddle, Venetian red, and umber.—*On Adulteration*, p. 166.

formed from considering the great use of vinegar made by the Romans. Whatever may have been the source of the opinion, there is no doubt of its correctness. Acetic acid plays that double part in the body which seems so important, of first an acid of a neutral salt, and then, in the form of carbonic acid, as the acid of an alkaline salt. But this valuable dietetic quality is partly counterbalanced in English vinegar by the unfortunate circumstance that sulphuric acid ($\frac{1}{1000}$th in weight) is allowed to be added to vinegar, and thus a strong acid is taken into the body, which is not only not useful in nutrition, but is hurtful from the tendency to form insoluble salts of lime. As the addition of sulphuric salts is not necessary,[1] and,

Fig. 86.—Cocoa, under parts, middle coat. × 190.

indeed, is not permitted on the Continent, it is to be hoped the Legislature will soon alter a system which has only the effect of injuring an important article of diet. The amount of vinegar which may be used may be from one to several ounces. On marches, the Romans mixed it with water as a beverage.

Examination of Vinegar.—Several kinds of vinegar are in the market, known by the Nos. 16, 18, 20, 22, 24. Nos. 22 and 24 are the best, and contain about 5 per cent. of pure glacial acetic acid. The weakest kinds contain less than 3 per cent. The Society of Public Analysts have adopted 3 per cent. as the minimum admissible.

Quality.—1. Take specific gravity; white wine vinegar varies from 1015 to 1022, malt vinegar from 1016 to 1019. If below this water has been added.

2. Determining acidity of 10 c.c. with the alkaline solution.[2] It is gene-

[1] The absence of *Anguillula Aceti* has been by some attributed to the use of sulphuric acid. See *Micrographic Dictionary*, article "Anguillula." In a sample examined at Netley, which swarmed with anguillulæ, there was only a trace of sulphuric acid.

[2] See Appendix A.

rally best to dilute the vinegar ten times with distilled water, and to take 10 c.c. of the diluted vinegar. Multiply the c.c. of alkaline solution used by 0·6; the result is acetic acid per cent.

Example.—10 c.c. of diluted vinegar took 8 c.c. of alkaline solution; $8 \times 0 \cdot 6 = 4 \cdot 8$ per cent. of acetic acid.

The acidity of English vinegar is chiefly caused by acetic and sulphuric acids, but it is usually calculated at once as glacial acetic acid. If it falls below 3 per cent.[1] water has probably been added. (The lowest noted by Hassall in 33 samples was 2·29.) If the specific gravity be low, and the acidity high, excess of sulphuric acid may have been added.

Sodium carbonate or ammonia gives a purplish precipitate in *wine* vinegar, but not in *malt* vinegar.

If excess of sulphuric acid be suspected, it must be determined by baryta; this requires care, as sulphates may be introduced in the water. Hydrochloric acid and barium chloride are added; the sulphate of barium collected, dried, weighed, and multiplied by 0·34305.

Adulterations.—Water; sulphuric acid in excess;[2] hydrochloric acid (uncommon); or common salt (detected by nitrate of silver and dilute nitric acid); pyroligneous acid (distil and re-distil the distillate, the residue will have the smell of pyroligneous acid); lead; copper from vessels (evaporate to dryness, incinerate, dissolve in weak nitric acid, divide into two parts, pass SH_2 through one, and test for copper in the other by ammonia, or by a piece of iron wire); corrosive sublimate (pass SH_2 through, collect precipitate); capsicum, pellitory, or other pungent substances (evaporate nearly to dryness, and dissolve in boiling alcohol, evaporate to syrup, taste; burnt sugar gives a bitter taste and a dark colour to the syrup).

The presence of copper in the vinegar used for pickles may be easily detected by simply inserting the bright blade of a steel knife.

Fig. 87.—White Mustard Seed.—Cuticle consisting of a perforated cellular epiderm and mucilage cells, some by expansion escaping through the cuticular openings after being placed in water.

[1] Hassall says 3·5 per cent.

[2] The presence of sulphuric acid may be detected, qualitatively, by adding a few drops of the vinegar to a piece of cane sugar, and evaporating on the water bath. The solution becomes black in proportion to the mineral acid present.—*Hassall.*

Sub-Section II.—Mustard.

Good mustard is known by the sharp acrid smell and taste. It is adulterated with turmeric (detected by microscope and liquor potassæ), wheat or barley starch (detected by microscope and iodine), and linseed

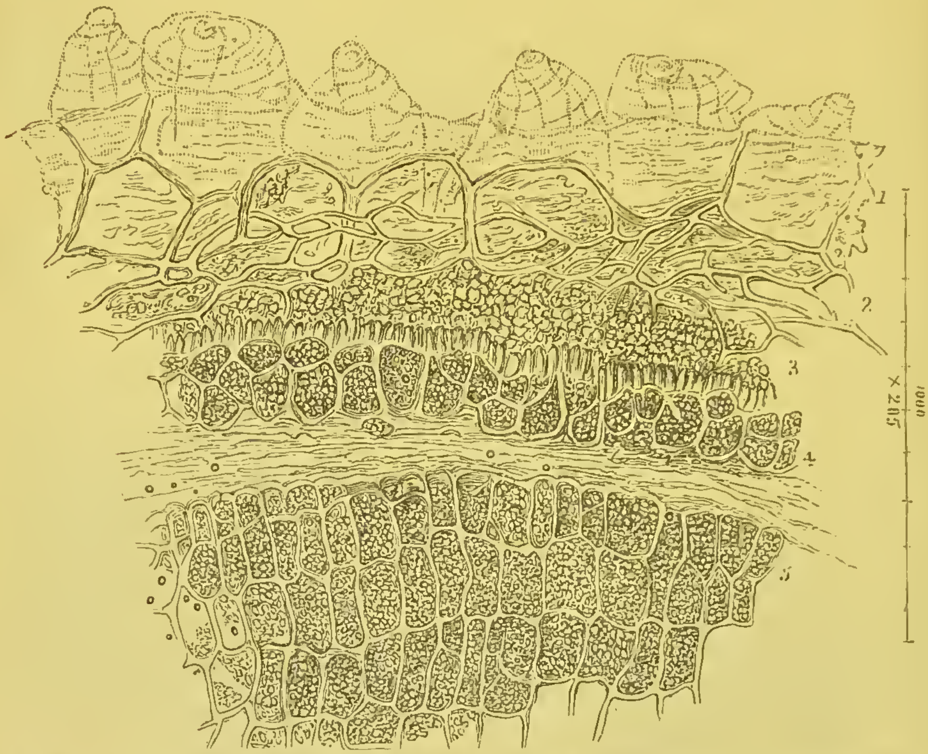

Fig. 88.—White Mustard Seed.—1, Outer coat, cuticle mucilage cells; 2, Fibrous reticular: 3, Small angular cells; 4, Large cells and very delicate membrane; 5, Interior of seed with a few minute oil globules.

(detected by microscope). Many samples of mustard are still mixed with turmeric and starch of some kind, but this has very much lessened since the

Fig. 89.—White Mustard Seed, central part. × 205.

passing of the Adulteration Act. Clay and plaster of Paris are sometimes added, and cayenne is added to bring up the sharpness, if much flour is used.

The microscopic characters of mustard are well marked. The outer coat

of the white mustard consists of a stratum of hexagonal cells, perforated in the centre, and other cells which occupy the centre portion of the hexagonal cells, and escape through the opening when swollen from imbibition of water; these cells are believed to contain the mucilage which is obtained when mustard is placed in water. There are two internal coats made up of small angular cells; the structure of the seed consists of numerous cells containing oil, but no starch. The black mustard has the same characters, without the infundibuliform cells.

Sub-Section III.—Pepper.

Pepper is adulterated with linseed, mustard husks, wheat and pea flour, rape cake, and ground rice. The microscope at once detects these adulterations.

Fig. 90.—Section of Black Pepper Berry, central portion.

The microscopic characters of pepper are rather complicated; there is a husk composed of four or five layers of cells and a central part. The cortex has externally elongated cells, placed vertically, and provided with a central cavity, from which lines radiate towards the circumference; then come some strata of angular cells, which, towards the interior, are larger, and filled with oil. The third layer is composed of woody fibre and spiral cells. The fourth layer is made up of large cells, which towards the interior become smaller and of a deep-red colour; they contain most of the essential oil of the pepper. The central part of the berry is composed of large angular cells, about twice as long as broad. Steeped in water, some of those cells become yellow, others remain colourless. It has been supposed that the yellow cells contain piperine, as they give the same reactions as piperine does: the tint, namely, is deepened by alcohol and nitric acid, and sulphuric acid applied to a dry section causes a reddish hue (Hassall).

White pepper is the central part of the seed, but some small particles of cortex are usually mixed with it. It is composed of cells containing very small starch grains. Hassall says that the central white cells are so hard they may be mistaken for particles of sand. A little care would avoid this. The starch grains are easily detected, however small, by iodine.

Pepper is largely adulterated with husks and palm-nut powder (Poivrette). No pure pepper should give less than 50 per cent. of reducing sugar on the ash-free substance ; palm-nut powder gives 23 per cent. (Leng). Neuss [1] recommends covering the powder with concentrated HCl : true pepper becomes intensely yellow, and from among it other substances can be picked out.

Fig. 91.—Transverse Section of Black Pepper Berry.

Pepper dust is merely the sweepings of the warehouses. Rape or linseed cake, cayenne and mustard husks, are mixed with pepper dust, and it is then sold as pepper.

Sub-Section IV.—Salt.

The goodness of salt is known by its whiteness, fine crystalline character, dryness, complete and clear solution in water. The coarser kinds, containing often chloride of magnesium, and perhaps lime salts, are darker coloured, more or less deliquescent, and either not thoroughly crystallised or in too large crystals.

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[1] *Pharm. Zeitung*, 1885.

SECTION IV.

LEMON AND LIME JUICE.

These juices contain free acids in large quantities, chiefly citric, and a little malic acid, sugar, vegetable albumen, and mucus.

The expressed juice of the ripe fruit of the *Citrus Limonum*, as ordered by the British Pharmacopœia, is said to have a specific gravity of 1·039, and to contain on an average 32·5 grains of citric acid in one fluid ounce.[1] The fresh juice of the lime (*Citrus Limetta*, or *Citrus acida*) has a rather less specific gravity (1·037), and contains less acid (32·22 grains per ounce).[2]

The very important Merchant Shipping Act,[3] which regulates the issue of lemon juice on board merchant vessels, does not define the strength; but it has been stated by Mr Stoddart[4] that the Board of Trade standard is a specific gravity of 1030 without spirit, and 30 grains of citric acid per ounce. It occasionally is as high as 1050.

As found in commerce, for merchant shipping, or used in the Royal Navy, the lime or lemon juice is chiefly prepared in Sicily or the West Indies; it is mixed with spirit (usually brandy or whisky, which gives it a slightly greenish-yellow hue), and olive oil is poured on the top.

Sugar is added to it when issued, to make it more agreeable to taste, in the proportion of half its weight. Lemon juice is usually issued in bottles containing three to four pints, not quite filled, and is covered with a layer of olive oil. About 1 ounce of brandy is added to each 10 ounces of juice. Sometimes the juice is boiled, and no brandy is added; the former kind keeps best (Armstrong). Both are equal in anti-scorbutic power (Armstrong). Good lemon juice will keep for some years, at least three years (Armstrong); bad juice soon becomes turbid, and then stringy and mucilaginous, and the citric and malic acids decompose, glucose and carbon dioxide being formed. Some turbidity and precipitate do not, however, destroy its powers.

As found in the market, it is frequently mixed with water, and sometimes with other acids. In 20 samples examined in 1868 by Mr Stoddart, 7 were genuine, 5 were watered, and 8 were artificial; tartaric acid being present in one, and sulphuric acid in another sample.[5]

In the examination the points which seem of consequence, in addition to the determination of the free acidity, are the fragrancy of the extract and the alkalinity of the ash, proving the existence of some alkaline citrate. The latter could, however, be imitated, but the fragrancy cannot be so.

Examination of Lemon Juice.

1. Pour into a glass, and mark physical characters; turbidity, precipitate, stringiness, &c. The taste should be pleasant, acid, but not bitter. Add lime water, and boil; if free citric acid is present, a large precipitate of

[1] Mr Stoddart (*Pharm. Jour.*, Oct. 1868) points out that the specific gravity is too high for the quantity of acid stated; there may, however, be other ingredients. He gives himself the specific gravity as 1·040 to 1·045, and the citric acid as 39 to 46 grains per ounce (citric acid, $C_6H_8O_7$). Mr Stoddart mentioned that when lemons are kept the citric acid decomposes, and glucose and carbon dioxide arise. But yet citric acid is made from damaged fruit.

[2] Stoddart, *op. cit.*, p. 205.

[3] *The Merchant Shipping Act*, 1867.

[4] *Pharm. Jour.*, Oct. 1868, p. 204.

[5] The lime-juice used in the Arctic Expedition, 1875-76, gave on analysis 27 grains of citric acid per ounce as issued, that is, after being fortified with about 15 per cent. of proof spirit. Before fortifying it contained 32 grains. (See analyses by Professor Attfield and Mr Bell, *Report of Committee on Scurvy*, pages xliii. and li.) Samples analysed at Netley showed a specific gravity of 1023 as issued, and 1035·7 after driving off the alcohol; the extract was about 8½ per cent. The unfortified juice froze at 25° F., the fortified remained liquid down to 15° F. Prolonged freezing at a temperature of nearly 0° F. produced no change in the character or amount of the constituents.

calcium citrate is formed, which redissolves as the solution cools. Evaporate very carefully to extract, to test the fragrancy, &c.

2. Take the specific gravity, remembering that spirit is present; then, if necessary, evaporate to one-half to drive off alcohol, dilute to former amount, and take specific gravity at 60° Fahr.

3. Determine acidity by alkaline solution.[1] Express the acidity as citric acid ($C_6H_8O_7$); 1 c.c. of the alkaline solution = 6·4 milligrammes of citric acid. As the acidity is considerable, the best way is to take 10 c.c. of the juice, add 90 c.c. of water, and take 10 c.c. of the dilute fluid, which will give the acidity of 1 c.c. of the undiluted juice. If the number of c.c. used for the diluted juice is multiplied by 2·8, it gives the acidity in grains per ounce.

4. Test for adulteration, viz.:—(*a*) *Tartaric Acid.*—Dilute and filter, if the lime juice be turbid; add a little solution of acetate of potash; stir well, without touching the sides of the glass, and leave for twenty-four hours; if tartaric acid be present the potassium tartrate will fall.

(*b*) *Sulphuric Acid.*—Add barium chloride after filtration, if necessary; if any precipitate falls, add a little water and a few drops of dilute hydrochloric acid to dissolve the barium citrate, which sometimes causes a turbidity.

(*c*) *Hydrochloric Acid.*—Test with silver nitrate and a few drops of dilute nitric acid.

(*d*) *Nitric Acid.*—This is an uncommon adulteration; the iron or brucine test can be used as in the case of water.

Factitious Lemon Juice.

It is not easy to distinguish well-made factitious lemon juice; about 552 grains of crystallised citric acid are dissolved in a wine pint of water, which is flavoured with essence of lemon dissolved in spirits. This corresponds to about 19 or 20 grains of dry citric acid per ounce. The flavour is not, however, like that of the real juice, and the taste is sharper. Evaporation detects the falsification.

Use of Lemon Juice.

In military transports, the daily issue of one ounce of lemon juice per head is commenced when the troops have been ten days at sea, and by the Merchant Shipping Act (1867) the same rule is ordered, except when the ship is in harbour, and fresh vegetables can be procured. It is mixed with sugar.

If dried vegetables can be procured, half the amount of juice will perhaps do.

In campaigns, when vegetables are deficient, the same rules should be enforced. On many foreign stations, where dysentery takes a scorbutic type (as formerly in Jamaica, and even of late years in China), lemon juice should be regularly issued.

Substitutes for Lemon Juice.

Citric acid is the best, or citrate of potassium; then perhaps vinegar, though this is inferior, and lowest of all is nitrate of potassium.[2] The tartrates, lactates, and acetates of the alkalies may all be used, but there are no good experiments on their relative anti-scorbutic powers on record. If milk is procurable, it may be allowed to become acid, and the acid then neutralised with an alkali. The fresh juices of many plants, especially species of cacti, can be used, the plant being crushed and steeped in water; and in case neither vegetables, lemon juice, nor any of the substitutes can be procured, we ought not to omit the trial of such plants of this kind as may be obtainable.

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[1] See Appendix A.

[2] On this point see Bryson's paper in the *Medical Times and Gazette*, 1850. Reference may also be made to a review on scurvy, which Dr Parkes contributed to the *British and Foreign Medical Chirurgical Review*, in October 1848, for evidence on the point.

CHAPTER XI.

EXERCISE.

A PERFECT state of health implies that every organ has its due share of exercise. If this is deficient, nutrition suffers, the organ lessens in size, and eventually, more or less degenerates. If it be excessive, nutrition, at first apparently vigorous, becomes at last abnormal, and, in many cases, a degeneration occurs which is as complete as that which follows the disuse of an organ. Every organ has its special stimulus which excites its action, and if this stimulus is perfectly normal as to quality and quantity, perfect health is necessarily the result.

But the term exercise is usually employed in a narrower sense, and expresses merely the action of the voluntary muscles. This action, though not absolutely essential to the exercise of other organs, is yet highly important, and, indeed, in the long run, is really necessary; the heart especially is evidently affected by the action of the voluntary muscles, and this may be said of all organs, with the exception, perhaps, of the brain. Not only the circulation of the blood, but its formation and its destruction, are profoundly influenced by the movement of the voluntary muscles. Without this muscular movement health must inevitably be lost, and it becomes therefore important to determine the effects of exercise, and the amount which should be taken.

SECTION I.

THE EFFECTS OF EXERCISE.

(*a*) *On the Lungs—Elimination of Carbon.*—The most important effect of muscular exercise is produced on the lungs. The pulmonary circulation is greatly hurried, and the quantity of air inspired, and of carbon dioxide expired, is marvellously increased. Dr Edward Smith investigated the first point carefully, and the following table shows his main results. Taking the lying position as unity, the quantity of air inspired was found to be as follows:—

Lying position, . .	1·00	Walking and carrying 63 lb,	3·84
Sitting, . . .	1·18	,, ,, 118 lb,	4·75
Standing, . . .	1·33	,, 4 miles per hour,	5·00
Singing, . . .	1·26	,, 6 ,,	7·00
Walking 1 mile per hour,	1·90	Riding and trotting, .	4·05
,, 2 ,,	2·76	Swimming, . . .	4·33
,, 3 ,,	3·23	Treadmill, . . .	5·50
,, and carrying 34 lb,	3·50		

The great increase of air inspired is more clearly seen when it is put in this way: under ordinary circumstances, a man draws in 480 cubic inches per minute; if he walks four miles an hour he draws in $(480 \times 5 =)$ 2400 cubic inches; if six miles an hour $(480 \times 7 =)$ 3260 cubic inches. Simul-

taneously, the amount of carbon dioxide in the expired air is increased (Scharling and many others).

The most reliable observations in this direction are those made by E. Smith, Hirn,[1] Speck,[2] and Pettenkofer and Voit.[3] As there is no doubt that the peculiar means of investigation render the experiments of the last-named authors as accurate as possible in the present state of science, they are given briefly in the following table :[4]—

Absorption and Elimination in Rest and Exercise.

Weight of man experimented upon, 60 kilos = 132 lb avds.	Absorption of Oxygen in Grammes.	Elimination in Grammes of—		
		Carbon Dioxide.	Water.	Urea.
Rest-day, ...	708·9	911·5	828·0	37·2
Work-day, ...	954·5	1284·2	2042·1	37·0
Excess on work-day (with exception of urea), ...	245·6	372·7	1214·1	− 0·2

In other words, during the work-day 3721 grains, or 8·66 ounces of oxygen, were absorbed in excess of the rest-day, and 5751 grains, or 13·15 ounces of carbon dioxide in excess, were evolved. Expressing this as carbon, an excess of 1568 grains, or 3·58 ounces, were eliminated on the work-day. There was an excess of oxidation of carbon equal to 41 per cent., and it must be remembered that the so-called "work-day" included a period of rest; the work was done only during the working hours, and was not excessive.

It will be observed from these experiments that a large amount of water was eliminated during exercise, while the urea was very slightly lessened.

It seems certain that the great formation of carbon dioxide takes place in the muscles ;[5] it is rapidly carried off from them, and if it is not so, it would seem highly probable that their strong action becomes impossible. At any rate, if the pulmonary circulation and the elimination of carbon dioxide are in any way impeded, the power of continuing the exertion rapidly lessens. The watery vapour exhaled from the lungs is also largely increased during exertion.

Muscular exercise is then clearly necessary for a sufficient elimination of carbon from the body, and it is plain that, in a state of prolonged rest, either the carboniferous food must be lessened or carbon will accumulate.

Excessive and badly arranged exertion may lead to congestion of the lungs, and even hæmoptysis. Deficient exercise, on the other hand, is one of the causes which favour those nutritional alterations in the lung which we class as tuberculous.

[1] Ludwig's *Phys.*, 2nd edit., Band i. p. 743.

[2] *Archiv des Vereins für wiss. Heilk.*, Band vi. pp. 285 and 289.

[3] *Zeitsch. für Biologie*, Bands ii. and iii., and Ranke's *Phys. des Menschen*, p. 551.

[4] The numbers given by Hirn and Speck are very accordant; they will be found quoted in the 2nd edition of this work, if it is wished to refer to them.

[5] See the observations of Valentin and others, and especially the experiments of Sczelkow (Henle's *Zeitschrift*, 1863, Band xvii. p. 106). The amount of CO_2 passing off from contracting muscles was indeed so great, and so much in excess of the O passing to them, that it was conjectured that carbonic acid must have been formed during contraction from substances rich in oxygen (such as formic acid), or that oxygen must have been obtained otherwise than from inspiration.

Certain rules flow from these facts. During exercise the action of the lungs must be perfectly free; not the least impediment must be offered to the freest play of the chest and the action of the respiratory muscles. The dress and accoutrements of the soldier should be planned in reference to this fact, as there is no man who is called on to make, at certain times, greater exertion. And yet, till a very recent date, the modern armies of Europe were dressed and accoutred in a fashion which took from the soldier, in a great degree, that power of exertion for which, and for which alone, he is selected and trained.

The action of the lungs should be watched when men are being trained for exertion; as soon as the respirations become laborious, and especially if there be sighing, the lungs are becoming too congested, and rest is necessary.

A second point is that the great increase of carbon excreted demands an increase of carbon to be given in the food. There seems a general accordance among physiologists that this is best given in the form of fat, and not of starch, and this is confirmed by the instinctive appetite of a man taking exertion, and not restrained in the choice of food.

A third rule is that, as spirits lessen the excretion of pulmonary carbon dioxide, they are hurtful during exercise; and it is perhaps for this reason, as well as from their deadening action on the nerves of volition, that those who take spirits are incapable of great exertion. This is now well understood by trainers, who allow no spirits, and but little wine or beer. It is a curious fact, stated by Artmann, that if men undergoing exertion take spirits, they take less fat. Possibly in reality they lessen the amount of exertion, and therefore require less fat. Water alone is the best liquid to train on.

A fourth rule is that, as the excretion of carbon dioxide (and perhaps of pulmonary organic matter) is so much increased, a much larger amount of pure air is necessary; and in every covered building (as gymnasia, riding-schools, &c.), where exercise is taken, the ventilation must be carried to the greatest possible extent, so soon does the air become vitiated.

(*b*) *On the Heart and Vessels.*—The action of the heart rapidly increases in force and frequency, and the flow of blood through all parts of the body, including the heart itself, is augmented. The amount of increase is usually from ten to thirty beats, but occasionally much more. After exercise, the heart's action falls below its normal amount; and if the exercise has been exceedingly prolonged and severe, may fall as low as fifty or forty per minute, and become intermittent. During exertion, when the heart is not oppressed, its beats, though rapid and forcible, are regular and equable; but when it becomes embarrassed, the pulse becomes very quick, small, and then unequal, and even at last irregular. When men have gone through a good deal of exertion, and then are called upon to make a sudden effort, the pulse may become very small and quick (160–170), but still retain its equability. There seems no harm in this, but such exertion cannot be long continued.

The ascension of heights greatly tries a fatigued heart. The accommodation of the heart to great exertion is probably connected with the easy flow of blood through its own structure.

Excessive exercise leads to affection of the heart,—rupture (in some few cases), palpitation, hypertrophy in a good many cases, and more rarely valvular disease. These may be avoided by careful training, and a due proportion of rest. Injuries to vessels may also result from too sudden or prolonged exertion. The sphygmographic observations of Dr Fraser [1] on the pulses of men after rowing show how much the pressure is increased.

[1] *Journal of Physiology*, Nov. 1868.

Deficient exercise leads to weakening of the heart's action, and probably to dilatation and fatty degeneration.

In commencing an unaccustomed exercise, the heart must be closely watched; excessive rapidity (120–140), inequality, and then irregularity, will point out that rest, and then more gradual exercise, are necessary, in order that the heart may be accustomed to the work.

(*c*) *On the Skin.*—The skin becomes red from turgescence of the vessels, and perspiration is increased; water, chloride of sodium, and acids (probably in part fatty) pass off in great abundance. Some nitrogen passes off in a soluble form (urea ?), but the amount is extremely small.[1] No gaseous nitrogen is given off in healthy men from the skin.

The amount of fluid passing off is not certain, but is very great. Speck's experiments show that it is at least doubled under ordinary conditions. Pettenkofer and Voit's experiments show even a larger increase. The usual ratio of the urine to the lung and skin excreta is reversed. Instead of being 1 to 0·5 or 0·8, it becomes 1 to 1·7 or 2, or even 2·5. This evaporation reduces and regulates the heat of the body, which would otherwise soon become excessive; so that, as long ago pointed out by Dr John Davy, the body temperature rises little above the ordinary temperature. No amount of external cold seems to be able to check the passage of fluid, though it may partly check the rapidity of evaporation. If anything check evaporation, the body-heat increases, and soon languor comes on and exertion becomes difficult.

During exertion there is little danger of chill under almost any circumstances; but when exertion is over, there is then great danger, because the heat of the body rapidly declines, and falls below the natural amount, and yet evaporation from the skin, which still more reduces the heat, continues.

The rules to be drawn from these facts are—that the skin should be kept extremely clean; during the period of exertion it may be thinly clothed, but immediately afterwards, or in the intervals of exertion, it should be covered sufficiently well to prevent the least feeling of coolness of the surface. Flannel is best for this purpose.

(*d*) *On the Voluntary Muscles.*—The muscles grow, become harder, and respond more readily to volition. Their growth, however, has a limit; and a single muscle, or group of muscles, if exercised to too great an extent, will, after growing to a great size, commence to waste. But this seems not to be the case when all the muscles of the body are exercised, probably because no single muscle or group of muscles can then be over-exercised. It seems to be a fact, however, that prolonged exertion, without sufficient rest, damages to a certain extent the nutrition of the muscles, and they become soft.

The rules to be drawn from these facts are, that all muscles, and not single groups, should be brought into play, and that periods of exercise must be alternated, especially in early training, with long intervals of rest.

(*e*) *On the Nervous System.*—The effect of exercise on the mind is not clear. It has been supposed that the intellect is less active in men who take excessive exercise, owing to the greater expenditure of nervous energy in that direction. But there is no doubt that great bodily is quite consistent with extreme mental activity; and, indeed, considering that perfect nutrition is not possible except with bodily activity, we should infer that sufficient exercise would be necessary for the perfect performance of mental work. Doubtless, exercise may be pushed to such an extreme as to leave no time for mental cultivation; and this is perhaps the explanation of the proverbial stupidity of the athletæ.

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[1] See "On the Excretion of Nitrogen by the Skin," by J. Byrne Power, L.C.P.I., *Proceedings of the Royal Society*, 1882, vol. xxxiii. p. 354.

Deficient exercise causes a heightened sensitiveness of the nervous system, a sort of morbid excitability, and a greater susceptibility to the action of external agencies.

(*f*) *On the Digestive System.*—The appetite largely increases with exercise, especially for meat and fat, but in a less degree, it would appear, for the carbo-hydrates. Digestion is more perfect, and absorption is more rapid. The circulation through the liver increases, and the abdominal circulation is carried on with more vigour. Food must be increased, especially nitrogenous substances, fats, and salts, and of these especially the phosphates and the chlorides.[1] The effects of exercise on digestion are greatly increased if it be taken in the free air, and it is then a most valuable remedy for some forms of dyspepsia.[2] Conversely, deficient exercise lessens both appetite and digestive power.

(*g*) *On the Generative Organs.*—It has been supposed that puberty is delayed by physical exertion, but perhaps the other circumstances have not been allowed full weight. Yet, it would appear that very strong exercise lessens sexual desire, possibly because nervous energy is turned in a special direction.

(*h*) *On the Kidneys.*—The water of the urine and the chloride of sodium often lessen in consequence of the increased passage from the skin. The urea is not much changed. The uric acid increases after great exertion; so also apparently the pigment; the phosphoric acid is not augmented[3] unless the exertion is excessive (North); the sulphuric acid is moderately increased (but invariably so according to North); the free carbonic acid of the urine is increased; the chlorides are lessened on account of the outflow by the skin; the exact amount of the bases has not been determined, but a greater excess of soda and potash is eliminated than of lime or magnesia; nothing certain is known as to hippuric acid, sugar, or other substances.[4]

(*i*) *On the Bowels.*—The effect of exercise is to lessen the amount, partly probably from lessened passage of water into the intestines. The nitrogen does not appear to be much altered.[5]

(*k*) *On the Elimination of Nitrogen.*—A great number of experiments have been made in the amount of nitrogen passing off by the kidneys during exercise.[6] The amount of urea has been usually determined, and the nitrogen has been calculated from this; Meissner has determined the amount of the creatin, and the creatinin;[7] while Fick and Wislicenus have compared the total nitrogen (by soda lime in the manner of Voit)

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[1] It is yet uncertain what kind of diet should be allowed during long marches in the tropics. Sir John Kirk states that in South Africa (10° and 17° S. lat.), during Livingstone's second expedition, a large quantity (2 ℔) of animal food was found to be essential; this was preferred, though any quantity of millets and leguminosæ could have been procured. Fat was taken in large quantities. It was found also that boiled was better than roast meat, because the men could eat more of it. No bad effect whatever was traceable to the use of this great amount of meat, even in the intensest heat.

[2] James Blake, *Pacific Medical and Surgical Journal*, 1860.

[3] Dr Parkes' experiments.

[4] In the careful observations made by Dr Pavy on Weston the pedestrian (*Lancet*, Dec. 1876), it was found that all the constituents were increased, except the chlorine and the soda, which were notably diminished, especially the chlorine; the magnesia was also diminished, but in a much less degree. In these experiments, however, the diet was not uniform, and the exercise was excessive.

[5] *Proceedings of the Royal Society*, No. 94, 1867, p. 52.

[6] For a statement of these experiments up to 1860, see Dr Parkes' work *On the Composition of the Urine*, 1860, p. 85. Since this time the chief experiments have been by Voit, Pettenkofer, J. Ranke, E. Smith, Haughton, Fick and Wislicenus, Byasson, Noyes, Meissner, Pavy, Parkes, North, and others. At present the subject is being investigated by a Committee of the British Association.

[7] Henle's *Zeitschrift at. Med.*, Band xxxii. p. 283.

as well as the ureal nitrogen, and Dr Parkes repeated their experiments.[1] The experiments have been usually carried on by determining the nitrogenous excretion in twenty-four hours with and without exercise; but in some the period during which work was actually performed was compared with previous and subsequent equal rest periods. Some experiments were performed on men who took no nitrogen as food; others were on men on a constant diet, so that the variation produced by the altering ingress of nitrogen was avoided as far as possible.

In this place it is impossible to give an account of these long researches, and therefore only a short summary can be given. (1) When a period of exercise is compared after an interval with one of rest (the diet being without nitrogen or with uniform nitrogen), the elimination of nitrogen by the kidneys is decidedly not increased in the exercise period. The experiments on this point are now so numerous that it may be stated without doubt. It is possible that the elimination may even be less during the exercise than during the rest period. This would appear in part from some of Ranke's and Fick and Wislicenus' experiments; from Noyes', as far as regards the urea; and from Meissner's, as far as the creatin (or creatinin) is concerned; while Dr Parkes found a decrease, which was not inconsiderable, both in the total nitrogen and in the urea. Additional observations are, however, much wanted on this point.

(2) When a day of rest is compared with a day of work (*i.e.*, a day with some hours of work and some hours of rest), the amount of nitrogen is almost or quite the same on the two days; if anything there is a slight increase in the nitrogen on the rest-day. In a day of part exercise and part rest, it is quite possible that there may be compensatory action, one part balancing the other, so as to leave the total excretion little changed.

(3) When a period of great exercise is immediately followed by an equal period of rest, the nitrogenous elimination is increased in the latter. Meissner's observations show that this is in part owing to increased discharge of creatin and creatinin; Parkes' observations also show an increase of non-ureal nitrogen. But the urea is also slightly increased in this period.

(4) When two days of complete rest are immediately followed by days of common exercise, the nitrogenous elimination diminishes during the first day of exercise (Parkes).

Mr W. North carried out a number of very careful experiments for several years, the details of which are given in *Proceedings of the Royal Society*.[2] In the main he confirms the observations of Parkes, but finds the effects of heavy labour to be more immediate and severe than was shown by those observations. North found that deprivation or output of nitrogen was followed by retention and absorption. There is also a tendency to the storage of nitrogen in the system under ordinary conditions, which shows a tendency to economy in the body. From this we might deduce the value of a good diet as providing a reserve against a period of deprivation or excessive work. A similar tendency to the storage of nitrogen was shown in the case of Weston, whose ingesta or egesta were examined by Winter Blyth.[3]

On the whole, if the facts have been stated correctly, the effect of exercise is certainly to influence the elimination of nitrogen by the kidneys, but within narrow limits, and the time of increase is in the period of rest succeeding the exercise; whereas during the exercise period the evidence, though not certain, points rather to a lessening of the elimination of nitrogen.

[1] *Proceedings of the Royal Society*, No. 89 (1867), and No. 94 (1867).
[2] Vols. xxxvi. p. 11, and xxxix. p. 443.
[3] *Proceedings of the Royal Society*, vol. xxxvii. p. 46.

It would appear from these facts that well-fed persons taking exercise would require a little more nitrogen in the food, and it is certain, as a matter of experience, that persons undergoing laborious work do take more nitrogenous food. This is the case also with animals. The possible reason of this will appear presently.

(*l*) *On the Temperature of the Body.*—As already stated, the temperature of the body, as long as the skin acts, rises little. Dr Clifford-Allbutt,[1] from observations made on himself when climbing the Alps,[2] found his temperature fairly uniform; the most usual effect was a slight rise, compensated by an earlier setting in of the evening fall. On two occasions he noticed two curious depressions, amounting to no less than 4°·5 Fahr.; he believes these were due to want of food, and not to exercise *per se*. In experiments on soldiers when marching, Dr Parkes found no difference in temperature; or if there was a very slight rise, it was subsequently compensated for by an equal fall, so that the mean daily temperature remained the same.[3] A decided rise in temperature during marching would therefore show lessening of skin evaporation, and may possibly be an important indication of impending sunstroke.

Changes in the Muscles.—The discussion on this head involves so many obscure physiological points, that it would be out of place to pursue it here to any length. The chief changes during action appear to be these:—There is a considerable increase in temperature (Helmholtz), which, up to a certain point, is proportioned to the amount of work. It is also proportioned to the kind, being less when the muscle is allowed to shorten than if prevented from shortening (Heidenhain); the neutral or alkaline reaction of the tranquil muscle becomes acid from para-lactic acid and acid potassium phosphate; the venous blood passing from the muscles becomes much darker in colour, is much less rich in oxygen, and contains much more carbonic acid (Sczelkow); the extractive matters soluble in water lessen, those soluble in alcohol increase (Helmholtz, in frogs); the amount of water increases (in tetanus, J. Ranke), and the blood is consequently poorer in water; the amount of albumen in tetanus is less according to Ranke, but Kühne has pointed out that the numbers do not justify this inference.[4] Baron J. von Liebig stated that the creatin is increased (but this was an inference from old observations on the *extractum carnis* of hunted animals, and required confirmation). Sarokin has stated the same fact in respect of the frog. The electro-motor currents show a decided diminution during contraction.

That great molecular changes go on in the contracting muscles is certain, but their exact nature is not clear; according to Ludimar Hermann,[5] there is a jelly-like separation and coagulation of the myosin, and then a resumption of its prior form, so that there is a continual splitting of the muscular structure into a myosin coagulum, carbon dioxide, and a free acid, and this constitutes the main molecular movement. But no direct evidence has been given of this.

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[1] *Alpine Journal*, May 1871.

[2] In the experiments made by Dr Calberla[1] and his two guides, during their ascents of Monte Rosa and the Matterhorn, in August 1874, no depressions were found as have been recorded by other observers. In none of the three persons did the temperature ever fall below 36°·4 C. (=97°·5 F.) or rise above 37°·8 C. (=100° F.). Dr Thomas, of Leipsic, in ascents in Savoy and Dauphiné (3500 and 3750 metres), could also find no lowering of temperature.

[3] *Proceedings of the Royal Society*, No. 127 and No. 136.

[4] *Lehrb. der Phys. Chem.*, 1868, p. 323.

[5] *Unters. über den Stoffwechsel der Muskeln*, von Dr L. Hermann; *Weitere Untersuch. zur phys. der Muskeln*, von Dr L. Hermann, 1867.

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[1] *Archiv der Heilkunde*, 1875, p. 276.

The increased heat, the great amount of carbon dioxide, and the disappearance of oxygen, combined with the respiratory phenomena already noted, all seem to show that an active oxidation goes on, and it is very probable that this is the source of the muscular action. The oxidation may be conceived to take place in two ways: either during rest oxygen is absorbed and stored up in the muscles and gradually acts there, producing a substance which, when the muscle contracts, splits up into lactic acid, carbon dioxide, &c.; or, on the other hand, during the contraction an increased absorption of oxygen goes on in the blood and acts upon the muscles, or on the substances in the blood circulating through the muscles.[1] The first view is strengthened by some of Pettenkofer and Voit's experiments, which show that during rest a certain amount of storage of oxygen goes on, which no doubt in part occurs in the muscles themselves. Indeed, it has been inferred that it is this stored-up oxygen, and not that breathed in at the time, which is used in muscular action. The increased oxidation gives us a reason why the nitrogenous food must be increased during periods of great exertion. An increase in the supply of oxygen is a necessity for increased muscular action; but Pettenkofer and Voit's observations have shown that the absorption of oxygen is dependent on the amount and action of the nitrogenous structures of the body, so that, as a matter of course, if more oxygen is required for increased muscular work, more nitrogenous food is necessary. But apart from this, although experiments on the amount of nitrogenous elimination show no very great change on the whole, there is no doubt that, with constant regular exercise, a muscle enlarges, becomes thicker, heavier, contains more solid matter, and in fact has gained in nitrogen. This process may be slow, but it is certain; and the nitrogen must either be supplied by increased food, or be taken from other parts.[2]

(A grain of nitrogen should be added in the food for every additional foot-ton of visible work.)

Although we do not know the exact changes going on in the muscles, it seems certain that regular exercise does produce in them an addition of nitrogenous tissue.

Whether this addition occurs, as usually believed, in the period of rest succeeding action when in some unexplained way the destruction, which it is presumed has taken place, is not only repaired, but is exceeded (a process difficult to understand), or whether the addition of nitrogen is actually made during the action of the muscle,[3] must be left undecided for the present.

The substances which are thus oxidised in the muscle, or in the blood circulating through it, and from which the energy manifested, as heat or muscular movement, is believed to be derived, may probably be of different kinds. Under ordinary circumstances, the experiments and calculations of Fick and Wislicenus, and others, and the arguments of Traube, seem sufficient to show that the non-nitrogenous substances, and perhaps especially the fats, furnish the chief substances acted upon. But it is probable that

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[1] Heaton (*Quarterly Journal of Science*, 1868) has given strong reasons for believing that the oxidation goes on in the blood.

[2] The way in which a vigorously acting part will rob the body of nitrogen, and thus in some cases cause death, is seen in many cases of disease. A rapidly growing cancer of the liver, for example, takes so much nitrogen as well as fat that it actually starves the rest of the body, and both voluntary muscles and heart waste. This is the case, though it is less marked, with growing tumours of other parts, and with great discharges. Powerful muscular action, if the food is not increased, evidently acts in something the same way; the health is greatly affected, and the heart especially fails.

[3] *Proceedings of the Royal Society*, No. 94, 1867.

the nitrogenous substances also furnish a contingent of energy.[1] The exact mode in which the energy thus liberated by oxidation is made to assume the form of mechanical motion is quite obscure.

The Exhaustion of Muscles.

There seems little doubt that the exhaustion of muscles is chiefly owing to two causes—first, and principally, to the accumulation in them of the products of their own action (especially para-lactic acid); and, secondly, from the exhaustion of the supply of oxygen. Hence rest is necessary, in order that the blood may neutralise and carry away the products of action, so that the muscle may recover its neutrality and its normal electrical currents, and may again acquire oxygen in sufficient quantity for the next contraction. In the case of all muscles these intervals of action and of exhaustion take place, in part even in the period which is called exercise, but the rest is not sufficient entirely to restore it. In the case of the heart the rest between the contractions (about two-thirds of the time), is sufficient to allow the muscle to recover itself perfectly.

The body after exertion absorbs and retains water eagerly; the water, though taken in large quantities, does not pass off as rapidly as usual by the kidneys or the skin, and instead of causing an augmented metamorphosis, as it does in a state of rest, it produces no effect whatever. So completely is it retained, that although the skin has ceased to perspire, the urine does not increase in quantity for several hours. The quantity of water taken is sometimes so great as not only to cover the loss of weight caused by the exercise, but even to increase the weight of the body.

We can be certain, then, of the absolute necessity of water during and after exercise, and the old rule of the trainer, who lessened the quantity of water to the lowest point which could be borne, must be wrong. In fact, it is now being abandoned by the best trainers, who allow a liberal allowance of liquid. The error probably arose in this way: if, during great exertion, water is denied, at the end of the time an enormous quantity is often drunk, more in fact than is necessary, in order to still the overpowering thirst. The sweating which the trainer had so sedulously encouraged is thus at once compensated, and, in his view, all has to be done over again. All this seems to be a misapprehension of the facts. The body must have water, and the proper plan is to let it pass in in small quantities and frequently; not to deny it for hours, and then to allow it to pass in in a deluge. The plan of giving it in small quantities frequently does away with two dangers, viz., the rapid passage of a large quantity of cold water into the stomach and blood, and the taking more than is necessary.[2]

In the French army, on the march, the men are directed not to drink;

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[1] Pavy shows, in his observations on Weston and Perkins, that the excess of nitrogen elimin..ed during the walking period, over the period of rest, was equivalent to about 542 foot-tons per man per diem. The total average daily work done he states at 1264 foot-tons, but this is an under-estimate, as the velocity was apparently greater than that of average walking, the coefficient of which ($\frac{1}{20}$) he assumes as the proportion of resistance. *N.B.*—One grain of nitrogen eliminated represents an amount of albuminoid expended capable of yielding about 2·4 foot-tons of potential energy. Although some of the excess of nitrogen eliminated during exercise, as noted above, may have been due to disintegration of muscle, part of it was due (undoubtedly) to changes in other tissues, but a considerable amount is due to direct oxidation of albuminous food.

[2] It is but right to say that many travellers of great experience have expressed great fear of water under exertion. Some of them have most strongly urged that "water be avoided like poison," and have stated that a large quantity of butter is the best preventive of thirst. At any rate, the butter may be excellent, but a little water is a necessity.

but, if very thirsty, to hold water in the mouth or to carry a bullet in the mouth. It is singular, in that nation of practical soldiers, to find such an order. Soldiers ought to be abundantly supplied with water, and taught to take small quantities when they begin to feel thirsty or fatigued. If they are hot, the cold water may be held in the mouth a minute or two before swallowing as a precaution; though there seems to be no evidence of any ill effects from drinking a moderate quantity of cold water, even during the greatest heat of the body.[1]

General Effect of Exercise on the Body, as judged of by the preceding facts.—The main effect of exercise is to increase oxidation of carbon, and perhaps also of hydrogen; it also eliminates water from the body, and this action continues, as seen from Pettenkofer and Voit's experiments, for some time; after exercise the body is therefore poorer in water, especially the blood; it increases the rapidity of circulation everywhere, as well as the pressure on the vessels, and therefore it causes in all organs a more rapid outflow of plasma and absorption,—in other words, a quicker renewal. In this way also it removes the products of their action, which accumulate in organs, and restores the power of action to the various parts of the body. It increases the outflow of warmth from the body by increasing perspiration. It therefore strengthens all parts. It must be combined with increased supply both of nitrogen and carbon (the latter possibly in the form of fat), otherwise the absorption of oxygen, the molecular changes in the nitrogenous tissues, and the elimination of carbon, will be checked. There must be also an increased supply of salts, certainly of chloride of sodium; probably of potassium phosphate and chloride. There must be proper intervals of rest, or the store of oxygen, and of the material in the muscles which is to be metamorphosed during contraction, cannot take place. The integrity and perfect freedom of action both of the lungs and heart are essential, otherwise neither absorption of oxygen nor elimination of carbon can go on, nor can the necessary increased supply of blood be given to the acting muscles without injury.

In all these points, the inferences deducible from the physiological inquiries seem to be quite in harmony with the teachings of experience.

SECTION II.

AMOUNT OF EXERCISE WHICH SHOULD BE TAKEN.

It would be extremely important to determine, if possible, the exact amount of exercise which a healthy adult, man or woman, should take. Every one knows that great errors are committed, chiefly on the side of defective exercise. It is not, however, easy to fix the amount even for an average man, much less to give any rule which shall apply to all the divers conditions of health and strength. But it is certain that muscular work is not only a necessity for health of body, but for mind also; at least it has seemed that diminution in the size of the body from deficient muscular work seems to lead in two or three generations to degenerate mental formation.

The external work which can be done by a man daily has been estimated at $\frac{1}{7}$th of the work of the horse; but if the work of a horse is considered to

[1] Horses also used to be, and by some are now, deprived or stinted of water during exercise. But in India the native horsemen give their horses drink as often as they can; and Dr Nicholson says this is the case with the Cape horses; even when the horses are sweating profusely the men will ride them into a river, bathe their sides, and allow them to drink.

be equal to the 1-horse power of a steam engine (viz. 33,000 lb raised 1 foot high per minute, or 8839 tons raised 1 foot high in ten hours), this must be an over-estimate, as $\frac{1}{7}$th of this would be 1263 tons raised 1 foot in a day's work of ten hours.[1] The hardest day's work of twelve hours noted by Dr Parkes was in the case of a workman in a copper rolling-mill. He stated that he occasionally raised a weight of 90 lb to a height of 18 inches, 12,000 times a day. Supposing this to be correct, he would raise 723 tons 1 foot high. But this much overpasses the usual amount. The same man's ordinary day's work, which he considered extremely hard, was raising a weight of 124 lb 16 inches 5000 or 6000 times in a day. Adopting the larger number, this would make his work equivalent to 443 tons lifted a foot; and this was a hard day's work for a powerful man. Some of the puddlers in the iron country, and the glass-blowers, probably work harder than this; but there are no calculations recorded. From the statement of a pedlar, his ordinary day's work was to carry 28 lb 20 miles daily. The weight is balanced over the shoulder,—14 lb behind and 14 lb in front. Assuming the man to weigh 160 lb, the work is equal to 443 tons lifted 1 foot. It would, therefore, seem certain that an amount of work equal to 500 tons lifted a foot is an extremely hard day's work, which perhaps few men could continue to do. 400 tons lifted a foot is a hard day's work, and 300 tons lifted a foot is an average day's work for a healthy, strong adult. The work usually calculated for a horse in the army is 3000 foot-tons,[2] and $\frac{1}{7}$th of this is just 430, nearly the work of the pedlar above mentioned.

The external work is thus 300 to 500 tons on an average; the internal work of the heart, muscles of respiration, digestion, &c., has been variously

[1] In some works on physiology a man's work of eight hours has been put as high as 316,800 kilogramme-metres, or 1020 tons lifted a foot; but this is far too much.

In this country the amount of work done is generally estimated as so many lb or tons lifted 1 foot. In France it is expressed as so many kilogrammes lifted 1 metre. Kilogramme-metres are converted into foot-pounds by multiplying by 7·233. To bring at once into tons lifted a foot, multiply kilogramme-metres by 0·003229. The following table may be useful, as expressing the amount of work done. It is taken from Dr Haughton's work (*A New Theory of Muscular Action*). The numbers are a little different from those given by Coulomb, as they were recalculated by Dr Haughton in 1863.

LABOURING FORCE OF MAN.

Kind of Work.	Amount of Work.	Authority.
Pile driving, ...	312 tons lifted 1 foot.	Coulomb.
Pile driving, ...	352 ,, ,,	Lamande.
Turning a winch, ...	374 ,, ,,	Coulomb.
Porters carrying goods and returning unladen, ...	325 ,, ,,	,,
Pedlars always loaded, . . .	303 ,, ,,	,,
Porters carrying wood up a stair and returning unloaded, . . .	381 ,, ,,	,,
Paviours at work, ...	352 ,, ,,	Haughton.
Military prisoners at shot drill (3 hours), and oakum picking, and drill, . .	310 ,, ,,	,,
Shot drill alone (3 hours), . .	160·7 ,, ,,	,,

It may be interesting to give some examples of work done in India by natives, which have been noted by Dr de Chaumont:—

A Leptcha hill-coolie will go from Punkabarree to Darjeeling (30 miles, and an ascent of 5500 feet) in three days, carrying 80 lb weight; the weight is carried on a frame supported on the loins and sacrum and aided by a band passed round the forehead.

Work per diem, about 500 tons lifted 1 foot.

Eight palanquin bearers carried an officer weighing 180 lb, and palanquin weighing 250 lb, 25 miles in Lower Bengal. Assuming each man weighed 150 lb, the work was 600 tons lifted a foot.

[2] F. Smith, *Veterinary Hygiene*, 1887.

estimated; the estimates for the heart alone vary from 122 to 277 tons lifted a foot. The former is that given by Haughton, who estimates the respiratory movements as about 11 tons lifted a foot in twenty-four hours. Adopting a mean number of 260 tons for all the internal mechanical work, and the external work of a mechanic being 300 to 500 tons, this will amount to from $\frac{1}{8}$th to $\frac{1}{7}$th of all the force obtainable from the food.

The exertion which the infantry soldier is called upon to undergo is chiefly drill, and carrying weights on a level or over an uneven surface.

The Reverend Professor Haughton, M.D., who is so well known for his important contributions to physiology and medicine, has shown that walking on a level surface at the rate of about 3 miles an hour is about equivalent to raising $\frac{1}{20}$th part of the weight of the body through the distance walked; an easy calculation changes this into the weight raised 1 foot. When ascending a height, a man of course raises his whole weight through the height ascended.

Using this formula,[1] and assuming a man to weigh 160 ℔ with his clothes, we get the following table—

Kind of Exercise.		Work done in Tons lifted one foot.
Walking 1 mile,		18·86
„ 2 „		37·72
„ 10 „		188·60
„ 20 „		377·20
„ 1 „	and carrying 60 ℔,	25·93
„ 2 „	„	51·86
„ 10 „	„	259·30
„ 20 „	„	518·60

It is thus seen that a march of 10 miles, with a weight of 60 ℔ (which is nearly the weight a soldier carries when in marching order, but without blanket and rations), is a moderate day's work. A 20 miles' march, with 60 ℔ weight, is a very hard day's work. As a continued labouring effort, Dr Haughton believes that walking 20 miles a-day, without a load (Sunday being rest), is good work (353 tons lifted a foot); so that the load of 60 ℔ additional would make the work too hard for a continuance.[2]

It must, however, be remembered that it is understood that the walking is on level ground, and is done in the easiest manner to the person, and that the weights which are carried are properly disposed. The labour is greatly increased if the walk is irksome, and the weights are not well adjusted. And this is the case with the soldier. In marching, his attitude is stiff; he observes a certain time and distance in each step; he has none of those shorter and longer steps, and slower and more rapid motion, which assist the ordinary pedestrian. It may be questioned, indeed, whether the formula does not under-estimate the amount of work actually done by the soldier. The work becomes heavier, too, *i.e.*, more exhausting, if it is done

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[1] The formula is $\frac{(W+W')\times D}{20\times 2240}$; where W is the weight of the person, W′ the weight carried; D the distance walked in feet; 20 the coefficient of traction; and 2240 the number of pounds in a ton. The result is the number of tons raised 1 foot. To get the distance in feet, multiply 5280 by the number of miles walked.

[2] Dr de Chaumont calculated the work done by the sledge-parties in the Arctic Expedition of 1875-76, and found that the Northern party (Markham's) did a mean of 574 foot-tons per man per diem, with a maximum of 859; the Western party (Aldrich's) did a mean of 443, and a maximum of over 600. Even this large amount was considered an under-estimate by the Commanders.—See *Report of Committee on Outbreak of Scurvy* (Blue Book), App. 24, p. 365.

in a shorter time; or, in other words, velocity is gained at the expense of carrying power.[1] The velocity, in fact, *i.e.*, the rate at which work is done, is an important element in the question, in consequence of the strain thrown on the heart and lungs. The Oxford boat races—rowing at racing speed (=1 mile in 7 minutes) in an Oxford eight-oar, or 18·56 foot-tons in 7 minutes,[2] is not apparently very hard work, but it is very severe for the time, as its effect is great on the circulatory system. Mr W. North's experiments[3] are remarkable, as having been done under circumstances of great precision. His weight was 132 ℔, and he carried 28 ℔—total weight, 160 ℔. In his first experiment he walked 30 miles at 4·28 per hour; work done, 712 foot-tons. Second experiment—32 miles at 4·57 per hour; work done, 728 foot-tons. Third experiment—33 miles at 4·71 per hour; work done, 843 foot-tons. Fourth experiment—47 miles at 4·7 per hour; work done, 1200 foot-tons.

Looking at all these results, and considering that the most healthy life is that of a man engaged in manual labour in the free air, and that the daily work will probably average from 250 to 350 tons lifted 1 foot, we can, perhaps, say, as an approximation, that every healthy man ought, if possible, to take a daily amount of exercise in some way, which shall not be less than 150 tons lifted 1 foot. This amount is equivalent to a walk of about 9 miles; but then, as there is much exertion taken in ordinary business of life, this amount may be in many cases reduced. It is not possible to lay

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[1] Dr Haughton (*Principles of Animal Mechanics*, 2nd ed. pp. 56 and 57) has determined, from the calculations of the MM. Weber, the coefficient of resistance for three velocities, as follows:—

Miles per hour.	Coefficient of Resistance.
1·818	$\frac{1}{28\cdot27}$
4·353	$\frac{1}{15\cdot70}$
10·577	$\frac{1}{7\cdot51}$

Interpolating between these numbers we can obtain the coefficients at other velocities. The following table shows the coefficients, the distance in miles that would equal 300 foot-tons for a man of 160 ℔, and the time in hours and minutes that would be required without rest:—

Velocity in Miles per hour.	Coefficient of Resistance.	Distance for Men of 160 ℔, to equal 300 foot-tons.	Time required in Hours and Minutes. H.	M.
1	$\frac{1}{38\cdot08}$ =	30·2	30	12
2	$\frac{1}{26\cdot74}$	21·2	10	36
3	$\frac{1}{20\cdot59}$	16·3	5	24
4	$\frac{1}{16\cdot74}$	13·3	3	18
5	$\frac{1}{14\cdot10}$	11·2	2	36
6	$\frac{1}{12\cdot18}$	9·6	1	36
7	$\frac{1}{10\cdot72}$	8·5	1	12
8	$\frac{1}{9\cdot58}$	7·6	0	57
9	$\frac{1}{8\cdot65}$	6·9	0	46
10	$\frac{1}{7\cdot89}$	6·3	0	38

or this may be stated thus: the residual resistance equivalent to the erect posture is equal to $\frac{1}{66\cdot44}$, or 0·01506; for every mile of velocity per hour add $\frac{1}{89\cdot51}$, or 0·01117; thus for 3 miles an hour we have $0\cdot01506+0\cdot01117\times3=0\cdot04857$, or $\frac{1}{20\cdot59}$, as above. The coefficient $\frac{1}{20}$ corresponds very nearly to 3·1 miles an hour, and this appears to be the rate at which the greatest amount of work can be done at the least expenditure of energy. (See table xviii., p. 186, *Lectures on State Medicine*, by F. de Chaumont.) As regards velocity, Dr Haughton states the "Law of Fatigue" as follows:—"When the same muscle (or group of muscles) is kept in constant action till fatigue sets in, the total work done, multiplied by the rate of work, is constant." The "Law of Refreshment" depends on the rate at which arterial blood is supplied to the muscles, and the "Coefficient of Refreshment" is the work restored to the muscles in foot-pounds per ounce of muscle per second; for voluntary muscle it is on an average 0·1309, and for the heart 0·2376, or exactly equal to the work of the heart, which never tires.

[2] *Training*, by A. Maclaren, p. 168.

[3] *Proc. Roy. Soc.*, xxxvi. p. 16.

down rules to meet all cases; but probably every man with the above facts before him could fix the amount necessary for himself with tolerable accuracy.

In the case of the soldier, if he were allowed to march easily, and if the weights were not oppressively arranged, he ought to do easily 12 miles daily for a long time, provided he was allowed a periodical rest. But he could not for many days, without great fatigue, march 20 miles a day with a 60 ℔ load, unless he were in good condition and well fed. If a greater amount still is demanded from him, he must have long subsequent rest. But all the long marches by our own or other armies have been made without weights, except arms and a portion of ammunition. Then great distances have been traversed by men in good training and condition.

SECTION III.

TRAINING.

The aim of the "Trainer" is to increase breathing power; to make the muscular action more vigorous and enduring, and to lessen the amount of fat. He arrives at his result by a very careful diet, containing little or no alcohol; by regular and systematic exercise; and by increasing the action of the eliminating organs, especially of the skin.

What the "Trainer" thus accomplishes is in essence the following: a concordant action is established between the heart and blood-vessels, so that the strong action of the heart during exercise is met by a more perfect dilatation of the vessels, and there is no blockage of the flow of blood; in the lungs, the blood not only passes more freely, but the amount of oxygen is increased, and the gradual improvement in breathing power is well seen when horses are watched during training. This reciprocal action of heart and blood-vessels is the most important point in training; the nutrition of nerves and muscular fibres improves from the constant action and the abundant supply of food; the tissue changes are more active, and elimination, especially of carbon, increases. A higher condition of health ensues, and, if not carried to excess, "training" is simply another word for healthy and vigorous living.[1]

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[1] Of course, over-training may be hurtful, but anything can be carried too far. Reference may be made to Dr Morgan's highly interesting and well-worked-out treatise on *University Oars*, to show that boating is beneficial. Dr Lee has published a useful little book, *Exercise and Training*, by R. Lee, M.D., with some good advice on training.

CHAPTER XII.

CLOTHING.

THE objects of clothing are to protect against cold and against warmth; all other uses will be found to resolve themselves into one or other of these.

The subject naturally divides itself into two parts—1*st*, the materials of clothing; and, 2*nd*, the make of the garments, which will be considered in Book II., and only as far as the soldier is concerned.

MATERIALS OF CLOTHING.

The following only will be described :—Cotton, linen, jute, wool, silk, leather, and india-rubber.

Chemical Reaction.—These materials are all easily distinguishable by microscopical characters, but certain chemical reactions may be useful. Wool and silk dissolve in boiling liquor potassæ or liquor sodæ of sp. gr. 1040 to 1050; cotton and linen are not attacked. Wool is little altered by lying in sulphuric acid, but cotton and linen change in half an hour into a gelatinous mass, which is coloured blue by iodine. Silk is slowly dissolved. Wool and silk take a yellow colour in strong nitric acid; cotton and linen do not. So also wool and silk are tinged yellow by picric acid; cotton or linen are not, or the colour is slight, and can be washed off. Silk, again, is dissolved by hot concentrated chloride of zinc, which will not touch wool. In a mixed fabric of silk, wool, and cotton, first boil in strong chloride of zinc, and wash; this gets rid of the silk; then boil in liquor sodæ, which dissolves the wool, and the cotton is left behind. Another reagent is recommended by Schlesinger, viz., a solution of copper in ammonia; this rapidly dissolves silk and cotton, and, after a longer time, linen; wool is only somewhat swollen by it. By drying thoroughly first, and after each of the above steps, the weight of the respective materials can be obtained.[1]

Cotton.—Microscopic Characters.—A diaphanous substance forming fibres about $\frac{1}{4000}$th of an inch in diameter, flattened in shape, and riband-like, with an interior canal which is often obliterated, or may contain some extractive matters, borders a little thickened, the fibres twisted at intervals (about 600 times in an inch). It has been stated that the fresh cotton fibre is a cylindrical hair with thin walls, which collapse and twist as it becomes

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[1] If other fabrics than those mentioned in the text have to be examined, the best book to consult is Dr Schlesinger's *Mikroscopische Untersuch. der Gespinnst-Fasern* (Zurich, 1873), where plates will be found of many of the fibres of commerce. The following are the chief reagents used by Schlesinger :—1*st*, Strong and weak sulphuric acid, to dissolve or swell out the fibres, and also, with iodine, to test for cellulose. 2*nd*, Nitric acid, especially to show the markings. 3*rd*, Chromic acid, as the best solvent for the intercellular substance, and for the swelling out in solution of the cellulose; it is often used with sulphuric acid. 4*th*, Dilute tincture of iodine, which is added to cellulose, and then sulphuric acid is used. 5*th*, Solution of copper, made by dissolving metallic copper in ammonia; this dissolves cell-membrane. 6*th*, Sulphate of aniline, which colours lignite yellow. 7*th*, Liquor potassæ (dilute), to render the fabrics transparent. He advises the fabric to be put on a slip of glass, and then a drop of water to be placed on it; then a needle should be drawn two or three times in the direction of the fibres, which will be easily detached. Then the fibre is laid on a glass and the reagent is applied.

dry. Iodine stains them brown; iodine and sulphuric acid (in very small quantities) give a blue or violet-blue; nitric acid does not destroy them, but unrolls the twist.

As an Article of Dress.—The fibre of cotton is exceedingly hard, it wears well, does not shrink in washing, is very non-absorbent of water (either into its substance or between the fibres), and conducts heat rather less rapidly than linen, but much more rapidly than wool.[1]

The advantages of cotton are cheapness and durability; its hard non-absorbing fibre places it far below wool as a warm water-absorbing clothing. In the choice of cotton fabrics there is not much to be said; smoothness, evenness of texture, and equality of spinning, are the chief points.

Fig. 92.—Cotton. × 285.

Fig. 93.—Linen. × 285.

In cotton shirting and calico, cotton is alone used; in merino and other fabrics it is used with wool, in the proportion of 20 to 50 per cent. of wool, the threads being twisted together to form the yarn.

Linen.—Microscopic Characters.—The fibres are finer than those of cotton, diaphanous, cylindrical, and presenting little swellings at tolerably regular intervals. The elementary fibres (of which the main fibre is composed) can be often seen in these swellings, and also at the end of broken threads which have been much used. The hemp fibre is something like this, but much coarser, and at the knots it separates often into a number of smaller fibres. *Silk* is a little like linen, but finer, and with much fewer knots.

As an Article of Clothing.—Linen conducts heat and absorbs water slightly better than cotton. It is a little smoother than cotton. As an article of

[1] Experiments on the conducting power of materials by Coulier (Professor of Chemistry at the Val de Grâce) and by Dr Hammond (late Surgeon-General, United States Army).

clothing it may be classed with it. In choosing linen regard is had to the evenness of the threads and to the fineness and closeness of the texture. The colour should be white, and the surface glossy. Starch is often used to give glossiness. This is detected by iodine, and removed by the first washing.

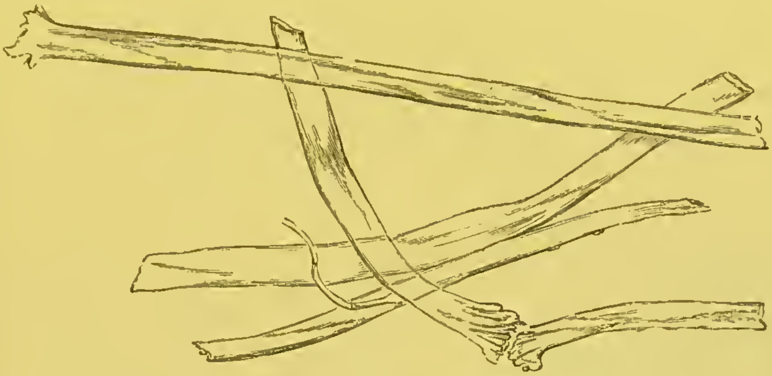

Fig. 94.—Silk. × 285.

Jute.—Jute is now very largely used, and appears to enter into the adulteration of most fabrics. Jute is obtained from the *Corchorus capsularis*,

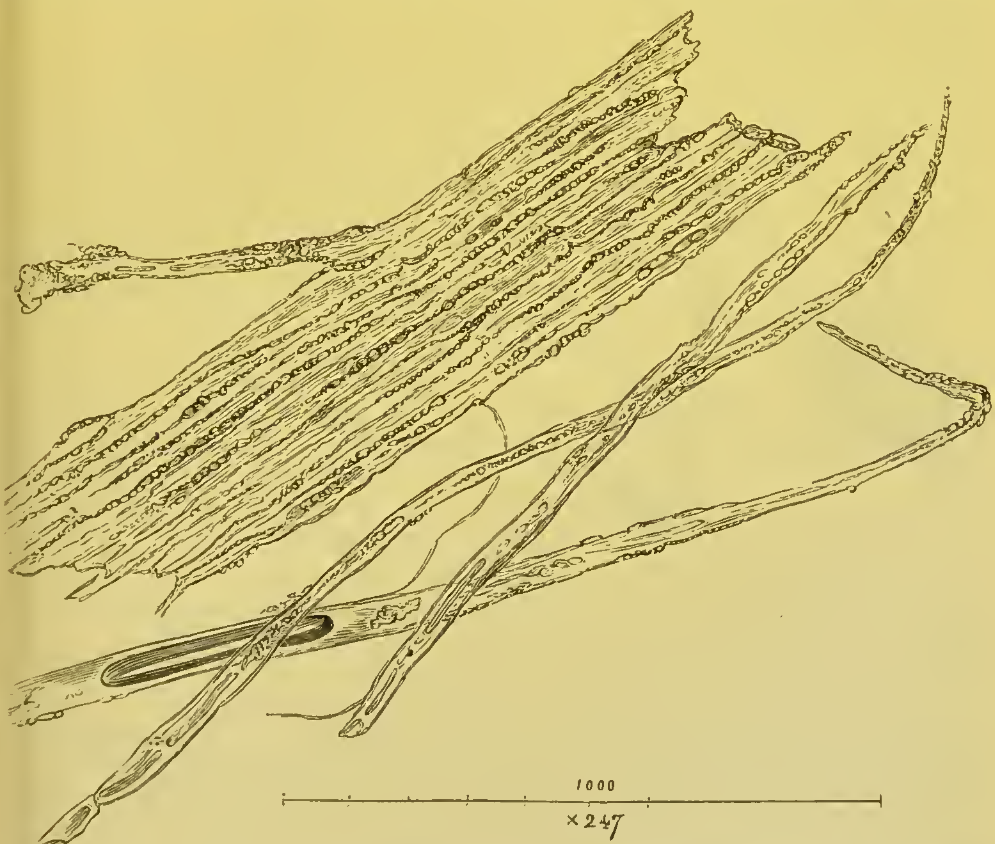

Fig. 95.—Jute—United and single elongated cellular tissues. Resinous (?) matter adhering more or less to all the fibres.

and comes to England from Russia and India. The fibres are of considerable length, are hollow, thickened, and with narrowings and constrictions in the tubular portions; sometimes an air-bubble may be in the fibre, as

shown in the drawing. The drawing, by Dr Maddox, shows the differences between the jute and cotton or linen.

Wool.—Microscopic Characters.—Round fibres, transparent or a little hazy, colourless, except when artificially dyed. The fibre is made up of a number of little cornets, which have become united. There are very evident slightly oblique cross markings, which indicate the bases of the cornets; and at these points the fibre is very slightly larger. There are also fine longitudinal markings. There is a canal, but it is often obliterated. When old and worn, the fibre breaks up into fibrillæ; and, at the same time, the slight prominence at the cross markings disappear, and even the markings become indistinct. By these characters old wool can be recognised. Size of fibres varies, but an average is given by the figure. The finest wools have the smallest fibres.

As an Article of Clothing.—Wool is a bad conductor of heat and a great absorber of water. The water penetrates into the fibres themselves and distends them (hygroscopic water), and also lies between them (water of interposition). In these respects it is greatly superior to either cotton or linen, its power of hygroscopic absorption being at least double in proportion to its weight, and quadruple in proportion to its surface.

Fig. 96.—Wool. × 285. Scale, $\frac{1}{1000}$th inch.

This property of hygroscopically absorbing water is a most important one. During perspiration the evaporation from the surface of the body is necessary to reduce the heat which is generated by the exercise. When the exercise is finished, the evaporation still goes on, and, as already noticed, to such an extent as to chill the frame. When dry woollen clothing is put on after exertion, the vapour from the surface of the body is condensed in the wool, and gives out again the large amount of heat which had become latent when the water was vaporised. Therefore a woollen covering, from this cause alone, at once feels warm when used during sweating. In the case of cotton and linen the perspiration passes through them, and evaporates from the external surface without condensation; the loss of heat then continues. These facts make it plain why dry woollen clothes are so useful *after* exertion.[1]

[1] Pettenkofer gives (*Zt. für Biol.*, Band i. p. 185) some experiments showing the hygroscopic power of wool as compared with linen. He shows that linen not only absorbs much less water, but parts with it much more quickly; thus, to cite one experiment, equal surfaces of linen and flannel being exposed to the air after being placed in equal conditions of absorption, the linen lost in 75 minutes 5·993 grammes, and the flannel only 4·858 grammes of water. Subsequently the evaporation from the linen lessened, as was to be expected, as it was becoming drier; that from the flannel continued to pass off moderately. The much greater cooling effect of linen is seen.

The porosity of clothing, *i.e.*, the rapidity with which air is driven through, is a point to be noted. By an equal pressure equivalent to a column of water 4·5 centimetres high, an area of 1 centimetre diameter forced air through as follows:—Through linen, 6·03 litres; flannel, 10·41; lambskin, 5·07; glove-leather, 0·15; wash-leather, 5·37; silk fabric, 4·14.

It thus appears that the warmest clothing (flannel) may be the most porous; mere porosity in fact, is only one element in the consideration.

In addition to this, the texture of wool is warmer, from its bad conducting power, and it is less easily penetrated by cold winds. The disadvantage of wool is the way in which its soft fibre shrinks in washing, and after a time becomes smaller, harder, and probably less absorbent.[1]

In the choice of woollen underclothing the touch is a great guide. There should be smoothness and great softness of texture; to the eye the texture should be close; the hairs standing out from the surface of equal length, not long and straggling. The heavier the substance is, in a given bulk, the better. In the case of blankets, the softness, thickness, and closeness of the pile, the closeness of the texture, and the weight of the blanket, are the best guides.

In woollen cloth the rules are the same. When held against the light, the cloth should be of uniform texture, without holes; when folded and suddenly stretched, it should give a clear ringing note; it should be very resistent when stretched with violence; the "tearing power" is the best way of judging if "shoddy" (old used and worked-up wool and cloth) has been mixed with fresh wool. A certain weight must be borne by every piece of cloth. At the Government Clothing Establishment at Pimlico, a machine is used which marks the exact weight necessary to tear across a piece of cloth. Schlesinger recommends the following plan for the examination of a mixed fabric containing shoddy:—Examine it with the microscope, and recognise if it contains cotton, or silk, or linen, besides wool. If so, dissolve them by ammoniacal solution of copper. In this way a qualitative examination is first made. Then fix attention on the wool. In shoddy both coloured and colourless wool fibres are often seen, as the fibres have been derived from different cloths which have been partially bleached; the colouring matter, if it remains, is different—indigo, purpurin, or madder. The diameter of the wool is never so regular as in fresh wool, and it changes suddenly or gradually in diameter, and suddenly widens again with a little swelling, and then thins off again; the cross markings or scales are also almost obliterated. When liquor potassæ is applied the shoddy wool is attacked much more quickly than fresh wool.

The dye also must be good, and of the kind named in the contract, and tests must be applied.

Leather.—Choice of leather: it should be well tanned, and without any marks of corrosion, or attacks of insects. The thinner kind should be perfectly supple.

Leather is not only used for shoes, leggings, and accoutrements; it is employed occasionally for coats and trousers. It is an extremely warm clothing, as no wind blows through it, and is therefore well adapted for cold, windy climates. Leather or sheepskin coats are very common in Russia, Turkey, Tartary, Persia, the Danubian Provinces, and everywhere where the cold north winds are felt. In Canada coats of sheepskin or buffalo-hide have been found very useful, and are commonly used by sentries.

Waterproof Clothing.—Like leather articles, india-rubber is an exceedingly hot dress, owing to the same causes, viz., impermeability to wind, and condensation and retention of perspiration. It is objected to by many on these grounds, and especially the latter; and Lévy informs us that the Council of Health of the French Army have persistently refused (and, in his opinion, very properly) the introduction of waterproof garments into

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[1] In washing woollen articles, they should never be *rubbed*, or *wrung*. They should be placed in a hot solution of soap, moved about, and then plunged into cold water; when the soap is got rid of they should be hung up to dry without wringing.

the army. If, however, woollen underthings are worn, the perspiration is sufficiently absorbed by those during the comparatively short time waterproof clothing is worn, and the objection is properly not valid unless the waterproof is continually worn.

The great use of waterproof is, of course, its protection against rain, and in this respect it is invaluable to the soldier, and should be largely used. By the side of this great use, all its defects appear to be minor evils.

India-rubber cloth loses in part its distensibility in very cold countries, and becomes too distensible in the tropics. It is also apt to rot by absorption of oxygen. Paraffined cloth is equally good, and the paraffin does not rot the fibre like common oil.

General Conclusions.

Protection against Cold.—For equal thicknesses, wool is much superior to either cotton or linen, and should be worn for all underclothing. In case of extreme cold, besides wool, leather or waterproof clothing is useful. Cotton and linen are nearly equal.

Protection against Heat.—Texture has nothing to do with protection from the direct solar rays; this depends entirely on colour. White is the best colour; then grey, yellow, pink, blue, black. In hot countries, therefore, white or light grey clothing should be chosen.

In the shade, the effect of colour is not marked. The thickness, and the conducting power of the material, are the conditions (especially the former) which influence heat.

Protection against Cold Winds.—For equal thicknesses, leather and india-rubber take the first rank; wool the second; cotton and linen about equal.

Absorption of Perspiration.—Wool has more than double the power of cotton and linen.

Absorption of Odours.—This partly depends on colour; and Stark's observations show that the power of absorption is in this order—black, blue, red, green, yellow, white. As far as texture is concerned, the absorption is in proportion to the hygroscopic absorption, and wool therefore absorbs more than cotton or linen.

Protection against Malaria.—It has been supposed that wearing flannel next the skin lessens the risk of malaria. As it is generally supposed that the poison of malaria enters either by the lungs or stomach, it is difficult to see how protection to the skin can prevent its action, except indirectly, by preventing chill in persons who have already suffered from ague. But the very great authority of Andrew Combe, drawn from experience at Rome, is in favour of its having some influence; and it has been used on the west coast of Africa for this purpose with apparently good results.

CHAPTER XIII.

INDIVIDUAL HYGIENIC MANAGEMENT.

This subject is an extremely large one, and the object of this book does not permit of its discussion. It would require a volume to itself. Only a few very general remarks can be made here. The application of general hygienic rules to a particular case constitutes individual management.

It is impossible to make general rules sufficiently elastic, and yet precise enough, to meet every possible case. It is sufficient if they contain principles and precepts which can be applied. While individual hygiene should be a matter of study to all of us, it is by no means desirable to pay a constant or minute attention to one's own health. Such care will defeat its object. We should only exercise that reasonable care, thought, and prudence which, in a matter of such moment, every one is bound to take.

Every man, for example, who considers the subject *bonâ fide*, is the best judge of the exact diet which suits him. If he understands the general principles of diet, and remembers the Hippocratic rule, that the amount of food and exercise must be balanced, and that evil results from excess of either, he is hardly likely to go wrong.

"Temperance and exercise" was the old rule laid down, even before Hippocrates,[1] as containing the essence of health; and if we translate temperance by "sufficient food for wants, but not for luxuries," we shall express the present doctrine.

The nutrition of the body is so affected by individual peculiarities, that there is a considerable variety in the kind of food taken by different persons. The old rule seems a good one, viz., while conforming to the general principles of diet, not to encourage too great an attention either to quantity or to quality, but avoiding what experience has shown to be manifestly bad, either generally or for the particular individual, to allow a considerable variety and change in amount from day to day, according to appetite.[2] Proper and slow mastication of the food is necessary; and it is extraordinary how many affections of the stomach called dyspepsia arise simply from faulty mastication, from deficient teeth, or from swallowing the food too

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[1] It is quite plain from the context that Hippocrates, by temperance, meant such an amount of food as would balance, and neither exceed nor fall short of the exercise. He had a clear conception of the development of mechanical force from, and its relation to, food. He lays down rules to show when the diet is in excess of exercise, or the exercise in excess of diet. In either case he traces disease.

[2] Celsus carried the plan of variety so far as to recommend that men should sometimes eat and drink more than is proper, and should sometimes not exceed; and Bacon has a remark which leads one to believe he held a similar opinion; but there can be no doubt of the incorrectness of this opinion. It has been truly said that the first general rule of Hippocrates, which prescribes continual moderation, is much truer, and the best writers on hygiene, ancient and modern, have decided against Celsus. Besides being erroneous, the rule of Celsus opens a door to intemperance, and, like a harmless sentence in Hippocrates, has been twisted to serve the argument of gourmands. Its influence is felt even at the present day. This much is certain, that probably 30 per cent. of the persons who consult physicians owe their diseases in some way to food, and in many cases they are perfectly aware themselves of their error or bad habit, but, with the singular inconsistency of human nature, either conceal it from the man to whom they are professing perfect openness, or manage to blind themselves to its existence.

rapidly. Many persons who are too thin are so from their own habits; they eat chiefly meat, and eat it very fast; they should eat slowly, and take more bread and starchy substances. Fat persons, on the other hand, by lessening the amount of starch, and taking more exercise, can lessen with the greatest ease the amount of fat to any amount. It must be remembered, however, that there is a certain individual conformation in this respect; some persons are normally fatter or thinner than others.

The exact amount of exercise must also be a matter of individual decision, it being remembered that exercise in the free air is a paramount condition of health, and that the healthiest persons are those who have most of it. As a rule, people take far too little exercise, especially educated women, who are not obliged to work, and the muscles are too often flaccid and ill-nourished.[1]

Attention to the skin is another matter of personal hygiene. The skin must be kept perfectly clean, and well clothed. Some writers, indeed, have advised that, if food be plentiful, few clothes be worn; but the best authors do not agree in this, but recommend the surface to be well protected. For cleanliness, cold bathing and friction hold the first rank. The effect of cold is to improve apparently the nutrition of the skin, so that it afterwards acts more readily, and when combined with friction, it is curious to see how the very colour and texture of the skin manifestly improve.

The effect of heat on the skin, and especially the action of the Roman or Turkish baths, and their action on health, have certainly not yet been properly worked out, in spite of the numerous papers which have been written. It has not been proved that the strong action of the Turkish bath is more healthy in the long run than the application of cold water. As a curative agent, it is no doubt extremely useful; but as a daily custom, it is yet *sub judice*. Certainly it should not be used without the concluding application of cold to the surface.

Attention has been often very properly directed to the effect of lead and mercurial hair-dyes. It may be worth while to notice that there is a case on record[2] in which not only was paralysis produced by a lead hair-wash, but lead was recovered from the base of the left hemisphere of the brain. Snuff containing lead has also caused poisoning.

The care of the bowels is another matter of personal hygiene, and is a matter of much greater difficulty than at first sight appears. Constipation, as allowing food to remain even to decomposition, as leading to distention and sacculation of the colon, and to hæmorrhoids, is to be avoided. But, on the other hand, the constant use of purgative medicine is destructive of digestion and proper absorption; and the use of clysters, though less hurtful to the stomach, and less objectionable altogether, is by no means desirable. On the whole, it would seem that proper relief of the bowels can be usually insured by exercise, and especially by bringing the abdominal muscles into play, and by the use of certain articles of diet—viz., pure water in good quantity with meals, the use of bran bread, honey, fruit, and such gently laxative food; and that if these do not answer well, it is better to allow a certain amount of constipation than to fall into the frequent use of purgative medicines.

The regulation of the passions must also be left to the individual. The

[1] Compare the imperfect development of the muscles of the arms in ladies, as shown by the low evening dresses, with the women of the working classes. No one can doubt which is the healthier or which is the more beautiful, until excess of work develops in the muscles of the labouring women the too hard outlines of middle life.

[2] Virchow's *Archiv*, Band viii. p. 177.

control of morals has baffled the exertions of the priest and the statesman; but perhaps the influence of sexual irregularities on health has never been made the subject of judicious education. The period of puberty corresponds with the most important period of growth, when the bones are consolidating and uniting, and both muscles and nerves are largely absorbing nourishment, and are developing to their fullest power. The too early use of sexual congress, and even more the drain on the system produced by solitary vice, arrests this development to a considerable extent, and prevents the attainment of the strength and endurance which would ensure a healthy, vigorous, and happy life. The venereal diseases, which so waste many of the younger men, form only an item in the catalogue of evils—evils which affect at a subsequent period wives and children, and, by undermining the health and happiness of the family, influence the state itself. We know that a widespread profligacy has eaten away the vigour of nations, and caused the downfall of states; but we hardly recognise that, in a less degree, the same causes are active among us, and never realise what a state might be if its citizens were temperate in all things. It may be difficult to teach these points to the young, and to urge upon them, for their own and other's sakes, that regulation of the passions which physiology teaches to be necessary for personal happiness, for the welfare of the offspring, and for healthy family life; but few can doubt that, in some way, the knowledge should be given.

The amount of mental work, and the practice of general good temper and cheerfulness and hope, are other points which each man must himself control. Great mental work can be borne well if hygienic principles of diet, exercise, &c., be attended to. The old authors paid great attention to the regimen of men engrossed in literary work, and laid down particular rules, insisting especially on a very careful and moderate diet, and on exercise.[1]

Hope and cheerfulness are great aids to health, no doubt, from their effect on digestion. Usually, too, they are combined with a quick and active temperament, and with rapid bodily movements and love of exercise.

The individual application of general hygienic rules will differ according to the sex and age,[2] and the circumstances of the person. In the case of children, we have to apply the general rules with as much caution and care as possible, as we must depend on external evidence to prove their utility. In the case of adults, individual experience soon shows whether a prescribed rule is or is not beneficial, and what modification must be made in it. It is not, however, every grown person who has the power to modify or change his condition. He may be under the influence of others who, in fact, arrange for him the circumstances of his life. But still, in no case is all self-control taken away; the individual can always influence the conditions of his own health.

Were the laws of health and of physiology better understood, how great would be the effect! Let us hope that matters of such great moment may not always be considered of less importance than the languages of extinct nations, or the unimportant facts of a dead history.

[1] Plutarch, whose rules on health are excellent and chiefly taken from Hippocrates, compares the over-studious man to the camel in the fable, who, refusing to ease the ox in due time of his load, was forced at last to carry not only the ox's own load, but the ox himself, when he died under his burden.

[2] Galen was the first who pointed out explicitly that hygiene rules must be different for infancy, youth, manhood, and old age—a fourfold division which is still the best. Pythagoras, Iccus, Herodicus, Hippocrates, Polybius, Diocles, Celsus, and others who preceded Galen, appear to have framed rules chiefly for male adults. Galen subdivided the subject much more systematically. (For a good short account of the early systems, see Mackenzie on *The History of Health, and the Art of Preserving it*, 1758.)

CHAPTER XIV.

DISPOSAL OF THE DEAD.

In densely populated countries the disposal of the dead is always a question of difficulty. If the dead are buried, so great at last is the accumulation of bodies that the whole country round a great city becomes gradually a vast cemetery.[1] In some soils the decomposition of bodies is very slow, and it is many years before the risk of impurities passing into air and water is removed.

After death the buried body returns to its elements, and gradually, and often by the means of other forms of life which prey on it, a large amount of it forms carbon dioxide, ammonia, carburetted hydrogen and hydrogen sulphide, nitrous and nitric acids, and various more complex gaseous products, many of which are very fœtid, but which, however, are eventually all oxidised into the simpler combinations. The non-volatile substances, the salts, become constituents of the soil, pass into plants, or are carried away into the water, percolating through the ground. The hardest parts, the bones, remain in some soils for many centuries, and even for long periods retain a portion of their animal constituents.

If, instead of being buried, the body is burned, the same process occurs more rapidly and with different combinations; carbon dioxide, carbon monoxide (?), nitrogen, or perhaps combinations of nitrogen, water, &c., are given off, and the mineral constituents, and perhaps a little carbon, if the combustion be incomplete, remain behind.

A community must always dispose of its dead either by burial in land or water, or by burning, or chemical destruction equivalent to burning, or by embalming and preserving. Accustomed as we are to land burial, there is something almost revolting, at first sight, at the idea of making the sea the sepulchre, or of burning the dead. Yet the eventual dispersion of our frames is the same in all cases; and it is probably a matter merely of custom which makes us think that there is a want of affection, or of care, if the bodies of the dead are not suffered to repose in the earth that bore them.

In reality, neither affection nor religion can be outraged by any manner of disposal of the dead which is done with proper solemnity and respect. The question should be placed entirely on sanitary grounds, and we shall then judge it rightly.

What, then, is the best plan of disposing of the dead, so that the living may not suffer?

It seems hardly likely that the practice of embalming or mummifying

[1] Nothing, perhaps, testifies more strongly to the antiquity and the extent of the ancient cities in Anatolia than the vast sepulchral remains. On the site of Old Dardanus, the mother of Troy, and stretching from the Hellespont for two or three miles into the hills, the whole country is honeycombed with tombs. It is the same in the neighbourhood of Troy. The burial of the dead, though practised by the most ancient nations, was afterwards superseded by burning, and was only subsequently returned to. As, therefore, these graves represent only a portion of the duration of the city, the immense assemblage of tombs is the more remarkable, and it is impossible to avoid the conclusion that these great cities must have flourished for periods far longer than those which have elapsed since London or Paris, for example, became large centres of population.

will ever again become common. What is the use of preserving for a few more years the remains which will be an object of indifference to future generations? The next logical step would be to enshrine these remains in some way so as to insure their preservation, and we should return to the vast burial mounds of Egypt. The question will lie between burial in the land or at sea, and burning.

At present the question is not an urgent one; but if the population of Europe continues to increase, it will become so in another century or two. Already in this country we have seen, in our own time, a great change; the objectionable practice of interment under and round churches in towns has been given up, and the population is buried at a distance from their habitations. For the present that measure will probably suffice, but in a few years the question will again inevitably present itself.

Burying in the ground appears certainly the most insanitary plan of the three methods. The air over cemeteries is constantly contaminated, and water (which may be used for drinking) is often highly impure. Hence, in the vicinity of graveyards two dangers to the population arise, and in addition, from time to time, the disturbance of an old graveyard has given rise to disease. It is a matter of notoriety that the vicinity of graveyards is unhealthy. How are these dangers to be avoided? The dead may be buried in more or less air-tight vaults; here decay is slow; the products form and escape slowly, though they must eventually escape; the air and water are less contaminated. But the immense expense of such a plan renders it impossible to adopt it for the community generally. Deep burying has the advantage of greater filtration, both for air and water, than shallow burying, and hence it is a good rule to make the grave as deep as possible, and to allow no more than one body in a grave. The admixture of quicklime has been advised; it absorbs some carbon dioxide, and forms calcium sulphide with the sulphur and hydrogen sulphide, but this itself soon decomposes, so that the expense of quicklime seems hardly commensurate with the result. Charcoal would absorb and oxidise the fœtid organic matter, and, if sufficiently cheap, would be a valuable substance to be heaped in graves; but its cost would be probably too great, nor does it entirely hinder putrefaction and the evolution of foul-smelling substances (H. Barker). If a body has to be kept unburied for some time, sawdust and sulphate of zinc, in the proportion of two parts to one, has been found by Herbert Barker [1] to be the best application; a thin layer is put over the dead body; or sawdust is sprinkled on the body, and then two or three inches of carbolic acid thrown over it.

The only means which present themselves, as applicable in all cases, are deep burial and the use of plants, closely placed in the cemetery. There is no plan which is more efficacious for the absorption of the organic substances, and perhaps of the carbon dioxide, than plants, but it would seem a mistake to use only the dark, slow-growing evergreens. The object should be to get the most rapidly growing trees and shrubs, and, in fact, there is no reason, except a feeling of sentiment, why we should introduce into our cemeteries the gloomy and melancholy cypress and yew. Mr Seymour Haden has called attention to the supposed advantages of perishable coffins, so that the putrefactive changes may be carried out as quickly as possible. And certainly, if burying is to continue, it seems reasonable that no undue obstacle should be placed in the way of changes which are sooner or later inevitable.

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[1] "Deodorisation and Disinfection," *British Medical Journal*, January 1866.

When, in the course of years, it becomes imperative to reconsider this question, and land burial will have to be modified, some arguments may present themselves to maritime nations in favour of burying in the sea rather than of burning. In the burial at sea, some of the body at least would go at once to support other forms of life, more rapidly than in the case of land burial, and without the danger of evolution of hurtful products.

Burning, or cremation, has attracted much attention of late years. In this country the subject has been discussed by Sir Henry Thompson and Mr Eassie, and abroad much has been written, especially in Germany and Italy, in both which countries the method has been practically tried. It would certainly appear that the body can be disposed of in a very short time and in an inoffensive manner, while the expense would unquestionably be much reduced if the practice became general. One hour appears sufficient to reduce a body to ashes, and it has been successfully carried out in this country at the Woking Crematory under the direction of the Cremation Society.

The only really valid argument against cremation is the possible concealment of crime, such as poisoning. This, however, might be guarded against by suitable precautions.

In time of war, and especially in the case of beleaguered fortresses, the disposal of the dead becomes often a matter of difficulty. In that case, burning may have to be resorted to. If the bodies are buried, they should always be at as great a distance as possible, and as deep as they can be. If procurable, charcoal should be thrown over them; if it cannot be obtained, sawdust and sulphate of zinc, or carbolic acid may be employed. Quicklime is also commonly employed, but it is less useful.

At Metz, in 1870, the following plan was adopted:—A pit of about 17 feet in depth was filled with dead, disposed as follows:—A row of bodies was laid side by side; above this a second row was placed, with the heads laid against the feet of the first row; the third row were placed across, and the fourth row in the same way, but with the heads to the feet of the former; the fifth row were placed as No. 1, and so on. Between each layer of bodies about an inch of lime, in powder, was placed. From 90 to 100 bodies were thus arranged on a length of 6½ feet, and reached to about 6 feet from the surface; the pit was then filled up with earth, and though 8400 bodies were put in that pit, there were no perceptible emanations at any time.

Around Metz the graves of men and horses and cattle were disinfected with lime, charcoal, and sulphate of iron. Immense exertions were made to clean and disinfect the camps and battle-fields, and in the month of May 1871 from 1200 to 1600 labourers were employed by the Germans. Wherever practicable, the ground was sown with oats or barley or grass. The hillocks formed by the graves were planted with trees.

In many cases, at Metz, bodies were dug up by the Germans when there was any fear of water-courses being contaminated, or if houses were near. On account of the danger to the workmen, graves containing more than six bodies were left untouched, and the work was always done under the immediate superintendence of a physician. The earth was removed carefully, but not far enough to uncover the corpse; then one end of the corpse was uncovered, and, as soon as uniform or parts of the body were seen, chloride of lime and sawdust, or charcoal and carbolic acid, put in; the whole earth round the body was thus treated, and the body at length laid bare, lifted, and carried away. The second body was then treated in the same way.

Near Sedan, where there were many bodies very superficially buried, burning was had recourse to. Straw mixed with pitch was put into the graves,

and was lighted; 1 ton of pitch sufficed for from 15 to 20 bodies. Opinions as to this practice were divided, and it is not certain how many graves were thus dealt with. It seems probable that only the surface of the body was burnt, and when many bodies were together in one grave some were not touched at all. On the whole, the experiment appears to have been unsuccessful.

The Belgian experience at Sedan was in favour of employing chloride of lime, nitric acid, sulphate of iron, and chlorine gas. Carbolic acid did not answer so well. The sulphate of zinc and charcoal, which Barker found so useful, was not tried.

Mr Eassic has called attention to the desirability of an ambulatory cremation furnace for the disposal of bodies in war. If such an arrangement proved practicable, it would unquestionably be of immense advantage from a hygienic point of view.

CHAPTER XV.

CLIMATE.

It is not easy to give a proper definition of climate. The effect of climate on the human body is the sum of the influences which are connected either with the solar agencies, the soil, the air, or the water of a place, and as these influences are in the highest degree complex, it is not at present possible to trace out their effects with any certainty.

With regard generally to the effect of climate on human life, it would seem certain that the facility of obtaining food (which is itself influenced by climate), rather than any of the immediate effects of climate, regulates the location of men and the amount of population. The human frame seems to acquire in time a wonderful power of adaptation. The Eskimos, when they can obtain plenty of food, are large, strong men (though nothing is known of their average length of life), and the dwellers in the hottest parts of the world (provided there is no malaria, and that their food is nutritious) show a stature as lofty and a strength as great as any dwellers in temperate climates. Peculiarities of race, indeed, arising no one knows how, but probably from the combined influences of climate, food, and customs, acting through many ages, appear to have more effect on stature, health, and duration of life than climate alone. Still, it would seem probable that, in climatic conditions so diverse, there arise some special differences of structure which are most marked in the skin, but may possibly involve other organs.

How soon the body, when it has become accustomed by length of residence for successive generations to one climate, can accommodate itself to, or bear the conditions of, the climate of another widely different place, is a question which can be only answered when the influences of climate are better known. The hypothesis of "acclimatisation" implies that there is at first an injurious effect produced, and then an accommodation of the body to the new conditions within a very limited time; that, for example, the dweller in northern zones passing into the tropics, although he at first suffers, acquires in a few years some special constitution which relieves him from the injurious consequences which, it is supposed, the change at first brought with it. There are, therefore, two assumptions, viz., of an injurious effect, and of a relief from it. Is either correct?

It may seem a bold thing to question the commonly received opinion that a tropical climate is injurious to a northern constitution, but there are some striking facts which it is difficult to reconcile with such an opinion. The army experience shows that, both in the West Indies and in India, the mortality of the soldier has been gradually decreasing, until, in some stations in the West Indies (as, for example, Trinidad and Barbadoes), the sickness and mortality among the European soldiers are actually less than on home service in years which have no yellow fever. In India, a century ago, people spoke with horror of the terrible climate of Bombay and Calcutta, and yet Europeans now live in health and comfort in both cities. In

Algeria the French experience is to the same effect. As the climate and the stations are the same, and the soldiers are of the same race and habits, what has removed the dangers which formerly made the sickness threefold and the mortality tenfold the ratio of the sickness and deaths at home?

The explanation is very simple: the deaths in the West Indies were partly owing to the virulence of yellow fever (which was fostered, though probably not engendered, by bad sanitary conditions) and the general excess of other febrile and dysenteric causes. The simple hygienic precautions which are efficacious in England have been as useful in the West Indies. Proper food, good water, pure air have been supplied, and, in proportion as they have been so, the deadly effects attributed to climate have disappeared. The effect of a tropical climate is, so to speak, relative. The temperature and the humidity of the air are highly favourable to decompositions of all kinds; the effluvia from an impure soil, and the putrescent changes going on in it, are greatly aggravated by heat. The effects of the sanitary evils which, in a cold climate like Canada, are partly neutralised by the cold, are developed in the West Indies, or in tropical India, to the greatest degree. In this way a tropical climate is evidently most powerful, and it renders all sanitary precautions tenfold more necessary than in the temperate zone. But all this is not the effect of climate, but of something added to climate.

Take away these sanitary defects, and avoid malarious soils or drain them, and let the mode of living be a proper one, and the European soldier does not die faster in the tropics than at home.

It must be said, however, that an element of uncertainty may be pointed out here. In our tropical possessions the European soldier serves now only for short periods (in the West Indies for three or four years, in India under the new regulations of short service, seven or eight years at most), and during this time he may be for some years on the hills, or at any rate in elevated spots. The old statistical reports of the army pointed out that the mortality in the West Indies augmented regularly with prolongation of service, and it may be said that, after all, the lessened sickness and mortality in the tropics is owing, in some degree, to avoidance by short service of the influence of climate. But as the whole long service was constantly passed under the unfavourable sanitary conditions now removed, it does not follow that the inference to be drawn from the statistical evidence as to length of service is really correct.

Facts prove, then, that under favourable sanitary conditions (general and personal) Europeans, during short service, may be as healthy as at home, as far as shown by tables of sickness and mortality, and it is not certain that long service brings with it different results.

It may, however, be urged that, admitting that a non-malarious tropical climate, *per se*, may not increase sickness or mortality during the most vigorous years of life (and it is then only that Europeans are usually subjected to it), it may yet really diminish health, lessen the vigour of the body, and diminish the expectation of life.

We have no evidence on the latter point. With respect to the former, it will be well to see what is known of the effects of climatic agencies on the frame.

The influences of locality and climate, as far as they are connected with soil and water, have been sufficiently discussed. The climatic conditions most closely (though by no means solely) connected with air will now be briefly reviewed. These are—temperature, humidity, movement, weight, composition, and electrical condition, and the amount of light.

SECTION I.

TEMPERATURE.

The amount of the sun's rays; the mean temperature of the air; the variations in temperature, both periodic and non-periodic; and the length of time a high or low temperature lasts, are the most important points. Temperature alone has been made a ground of classification.

(*a*) *Equable, limited,* or *insular* climates; *i.e.,* with slight yearly and diurnal variations.

(*b*) *Extreme, excessive,* or *continental; i.e.,* with great variations.

The terms *limited* and *extreme* might be applied to the amplitude of the yearly fluctuation (*i.e.,* difference between hottest and coldest month), while *equable* and *excessive* might be applied especially to the non-periodic variations, which are slight in some places and extreme in others.

A limited climate is generally an equable one, and an extreme climate (with great yearly fluctuation) is generally an excessive one (with great undulations).

The effects of heat cannot be dissociated from the other conditions; it is necessary, however, briefly to notice them.

The effect of a certain degree of temperature on the vital processes of a race dwelling generation after generation on the same spot, is a question which has as yet received no sort of answer. Does the amount of heat *per se,* independent of food and all other conditions, affect the development of mechanical force and temperature, and the coincident various processes of formation and destruction of the tissues? Is there a difference in these respects, and in the resulting action of the eliminating organs, in the inhabitants of the equator and of 50° or 60° N. lat.? This is entirely a problem for the future, but there is no class of men who have more opportunities of studying it than army surgeons.

The problem of the influence of temperature is generally presented to us under the form of a dweller in a temperate zone proceeding to countries either colder or hotter than his own. It is in this restricted sense we shall now consider it.

With regard to the effect on the Anglo-Saxon and Celtic races of going to live in a climate with a lower mean temperature and greater variations than their own, we have the experience of Canada, Nova Scotia, and some parts of the Northern American States. In all these, if food is good and plentiful, health is not only sustained, but is perhaps improved. The agricultural and out-door life of Canada or Nova Scotia is perhaps the cause of this; but certain it is that in those countries the European not only enjoys health, but produces a progeny as vigorous, if not more so, than that of the parent race.

The effects of heat exceeding the temperate standard must be distinguished according to origin; radiant heat, or the direct rays of the sun, and non-radiant heat, or that of the atmosphere. In the latter case, in addition to heat, there is more or less rarefaction of the air, and also coincident conditions of humidity and movement of the air, which must be taken into account. The influence, again, of sudden transitions from heat to cold, or the reverse, has to be considered. Europeans from temperate climates flourish, apparently, in countries not much hotter than their own, as in some parts of Australia, New Zealand, and New Caledonia, though it is yet too soon to speculate whether the vigour of the race will improve or otherwise.

But there is a general impression that they do not flourish in countries much hotter, *i.e.*, with a yearly mean of 20° Fahr. higher, as in many parts of India; that the race dwindles, and finally dies out; and therefore that no acclimatisation of race occurs. And certainly it would appear that in India there is some evidence to show that the pure race, if not intermixed with the native, does not reach beyond the third generation. Yet it seems only right to say that so many circumstances besides heat and the other elements of climate have been acting on the English race in India, that any conclusion opposed to acclimatisation must be considered as based on scanty evidence. We have not gauged on a large scale the effects of climate pure and simple, uncomplicated with malaria, bad diet, and other influences adverse to health and longevity.[1]

(*a*) *Influence of the Direct Rays of the Sun.*—It is not yet known to what temperature the direct rays of the tropical sun can raise any object on which they fall. In India, on the ground, the uncovered thermometer will mark 160°, and perhaps 212° (Buist); and in this country, if the movement of air is stopped in a small space, the heat in the direct sun's rays can be raised to the same point. In a box, with a glass top, Sir H. James found the thermometer mark 237° Fahr., when exposed to the rays of the sun, on the 14th July 1864.[2] In experiments on frogs, when temperature much over the natural amount is applied to nerves, the electrical currents through them are lessened, and at last stop.[3] E. H. Weber's observations show that for men the same rule holds good; the most favourable temperature is 30° R. (= 99°·5 Fahr.).[4] It appears also from Kühne's experiments that the heat of the blood of the vertebrata must not exceed 113° Fahr., for at that temperature the myosin begins to coagulate.[5] Perhaps this fact may be connected with the pathological indication that a very high temperature in any disease (over 110° Fahr.) indicates extreme danger.

To what temperature is the skin of the head and neck raised in the tropics in the sun's rays? No sufficient experiments have been made, either on this point or on the heat in the interior of caps and hats with and without ventilation. Doubtless, without ventilation, the heat above the head in the interior of the cap is very great. It is quite possible, as usually assumed, that with bad head-dresses the heat of the skin, bones, and possibly even of the deep nerves and centres (the brain and cord), may be greater than is accordant with perfect preservation of the currents of the nerves, or of the necessary temperature of the blood, or with the proper fluidity of some of the albuminous bodies in the muscles or nerves.

The difficulty of estimating the exact effect of the solar rays is not only caused by the absence of a sufficient number of experiments, but by the common presence of other conditions, such as a hot, rarefied, and perhaps impure air, and heat of the body produced by exercise which is not attended by perspiration. Two points are remarkable in the history of sunstroke, viz., the extreme rarity of sunstroke in mid ocean[6] and at great

[1] In India the mortality of Eurasians (that is, the mixed race of British, Portuguese, Hindū, Malay blood, mixed in all degrees) appears to be below that of the most healthy European service, viz., the Civil Service. Mr Tait's facts, "On the Mortality of Eurasians" (*Statistical Journal*, September 1864), would show that this mixed race will maintain itself in India.

[2] Mr Symons has also obtained temperature above 212° F. by the same means.

[3] Eckhard, *Henle's Zeitsch.*, Band x. p. 165, 1851.

[4] Weber, *Ludwig's Phys.*, 2nd ed., vol. i. p. 126.

[5] Ludwig's *Lehrb. der Phys.*, Band ii. p. 732. For a collection of data, see Dr H. C. Wood, jun., *Thermic Fever*, 1872, p. 50.

[6] The cases of insolation in a narrow sea like the Red Sea do not invalidate this rule.

elevations.[1] In both cases the effect of the sun's rays, *per se*, is not less, is even greater, than on land and at sea-level; yet in both sunstroke is uncommon; the temperature of the air, however, is never excessive in either case.

The effect of the direct rays on the skin is another matter requiring investigation. Does it aid or check perspiration? That the skin gets dry there is no doubt, but this may be merely from rapid evaporation. But if the nervous currents are interfered with, the vessels and the amount of secretion are sure to be affected, and on the whole it seems probable that a physiological effect adverse to perspiration is produced by the direct rays of the sun. If so, and if this is carried to a certain point, the heat of the body must rise, and, supposing the same conditions to continue (intense radiant heat and want of perspiration), may pass beyond the limit of the temperature of possible life (113° Fahr.).[2]

The effect of intense radiant heat on the respiration and heart is another point of great moment which needs investigation.

The pathological effect produced by the too intense direct rays of the sun is seen in one or two forms of insolation, and consists in paralysis of the heart or the respiration.

A form of fever (the *Causus* of some writers, or thermic fever) has been supposed to be caused by the direct rays of the sun combined with excessive exertion. Dr Parkes mentions a case of this kind which corresponded closely to the description in books. The fever lasted for several days, and its type was not in accordance with the hypothesis that it was a malarious fever, or febricula, or enteric. No thermometric observations were made on the patient.

(*b*) *Heat in Shade.*—The effect of high air temperature on the native of a temperate climate passing into the tropics has not been very well determined, and some of the conclusions are drawn from experiments on animals exposed to an artificial temperature.

1. The *temperature* of the body does not rise greatly—not more than 0°·5 or 1° Fahr. (John Davy); from 1° to 2½° and 3° (Eydaux and Brown-Séquard). In some experiments not published the late Dr Becher determined his own temperature in a very careful way during a voyage round the Cape to India. He found the body-heat increased, and in the proportion of 0°·05 Fahr. for every increase of 1° Fahr. in the air. Rattray also found a decided increase, varying from 0°·2 Fahr. to 1°·2 Fahr.; the greatest increase was in the afternoon. We may conclude that the tropical heat raises the temperature of the body of a new-comer, probably because the evaporation from the skin is not capable of counterbalancing the great additional external heat, but it is now known that in old residents the same fact does not hold good. Brigade-Surgeon J. C. Johnston has recorded a very careful series of experiments, made on soldiers of at least three years' service in India,[3] in the station of Bellary. The average of one series was 97°·63, and of another 97°·94, thus showing if anything a slight lowering from the normal temperature, 98°·4. Surgeon-Major Boileau, from a long series of observations

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[1] This may be due to the absence of radiation from the ground; ground radiation affects unprotected thermometers vary markedly.

[2] In the Turkish bath it may sometimes be observed, that on entering the hottest chamber the skin, which had previously been acting freely, becomes dry. A feeling of oppression accompanies this, but relief is experienced so soon as perspiration is re-established. This would seem to point more to an actual arrest of function than to a mere drying up of the secretion. The same thing in a modified degree may occur in a tropical climate, in which case the intensity of fever will depend upon the time that elapses before accommodation is reached.

[3] *Army Medical Reports*, vol. xviii. p. 255.

in the West Indies, came to the conclusion that there was no material rise. The temperature of the body is the result of the opposing action of two factors—1*st*, of development of heat from the chemical changes of the food, and by the conversion of mechanical energy into heat, or by direct absorption from without; and, 2*nd*, and opposed to this, of evaporation from the surface of the body, which regulates internal heat. So beautifully is this balance preserved, that the stability of the animal temperature in all countries has always been a subject of marvel. If anything, however, prevents this evaporation, radiation and the cooling effect of moving wind cannot cool the body sufficiently in the tropics. Then, no doubt, the temperature of the body rises, especially if in addition there is muscular exertion and production of heat from that cause. The extreme discomfort always attending abnormal heat of body then commences. In experiments in ovens, Blagden and Fordyce bore a temperature of 260° with a small rise of temperature (2½° Fahr.), but the air was dry, and the heat of their bodies was reduced by perspiration; when the air in ovens is very moist and evaporation is hindered, the temperature of the body rises rapidly.[1]

2. The *respirations* are lessened in number (Vierordt, Ludwig) in animals subjected to heat. According to Vierordt, less carbonic acid and presumably less water are eliminated. Rattray[2] proved by a great number of observations that the number of respirations is lessened in persons passing from a cold to a hot climate. The amount of diminution varies; in some experiments the fall was from 16·5 respirations per minute in England, in winter, to 12·74 and 13·74 in the tropics. In another series of experiments the fall was from 17·3 respirations per minute to 16·1; the breathing is also gentler, *i.e.*, less deep. Rattray has also shown that the spirometric measurements of the expired air ("vital capacity" of Hutchinson) increases in the tropics and falls in temperate climates, the average variation being about 8·7 per cent. of the total spirometric measurements.[3] This will hold good at all ages, but is less at either extreme of life, and is most marked in persons of largest frame and most full blooded. The explanation of this spirometric increase in the respiratory action of the lungs, as compared with the lessened number of inspirations, is to be found, according to Rattray, in a lessened proportion of blood and a larger proportion of air in the lungs in the tropics, and this is borne out by a fact presently to be noted, of the lessened weight of the lungs in Europeans in the tropics.

The effect of the lessened number of respirations is (in spite of the spirometric increase) to reduce the total respiratory action considerably. Rattray has shown that the average amount is in the temperate zone (temp. = 54° Fahr.), 239·91 cubic inches per minute, while in the tropics (= 82° Fahr.) only 195·69 cubic inches were inspired, so that there is a difference of 38·65 cubic feet in twenty-four hours, or 18·43 per cent. in favour of a temperate climate.[4] If 10 ounces of carbon are expired in the temperate

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[1] It rises even 7° to 8° Fahr. (Ludwig, *Lehrb. des Phys.*, 2nd edit., b. ii. p. 730). Obernier's later observations are confirmatory (*Der Hitzschlag*, Bonn, 1867). Obernier confirms the pathology generally received in this country. From an observation of four cases of sunstroke, and from thirty-three experiments on animals exposed to artificial heat, he traces all the effects to the augmented temperature of the body, which cannot cool by evaporation from the surface and lungs as usual. Dr H. C. Wood, jun., of Philadelphia (*Thermic Fever or Sunstroke*, 1872), also holds that the "efficient cause of sunstroke is the excess of temperature."

[2] "On the Effects of Change of Climate on the Human Economy," by A. Rattray, M.D., Surgeon, R.N., *Proceedings of the Royal Society*, Nos. 122-126, 139 (1869-72).

[3] *Proceedings of the Royal Society*, No. 139, p. 2.

[4] These quantities seem very small; with 16 or 17 respirations per minute, the number of cubic inches per respiration would be only 13 to 15; whereas 30 is usually adopted as the average for adults.

zone, only 8·157 ounces would be expired in the tropics. Is there, then, greater excretion of carbon from the skin, or, as used to be supposed, from the liver?

Dr Francis (Bengal Army) has observed that the lungs are lighter after death in Europeans in India than the European standard. Dr Parkes made a similar observation many years ago, and recorded it in a work on cholera,[1] but the facts were few. If this statement be confirmed, it would show a diminished respiratory function, and would accord with Rattray's observations.

3. The *heart's* action has been usually stated to be quickened in the tropics, but Rattray's numerous observations show that this is incorrect; the average pulse in the tropics was lower by 2½ beats per minute than in the temperate zone. In experiments on animals, moderate heat does not quicken the heart, but great heat does.

4. The *digestive* powers are somewhat lessened, there is less appetite, less desire for animal food, and more wish for cool fruit. The quantity of bile secreted by the liver is not increased, if the stools are to be taken as a guide (Marshall, in 1819, John Davy, Morehead, Parkes), though Lawson believes that an excess of colouring matter passes out with the stools; nothing is known of the condition of the usual liver work.

5. The *skin* acts much more than usual (an increase of 24 per cent. according to Rattray), and great local hyperæmia and swelling of the papillæ occur in new-comers, giving rise to the familiar eruption known as "prickly heat." In process of time, if exposed to great heat, the skin suffers apparently in its structure, becoming of a slight yellowish colour from, probably, pigmentary deposits in the deep layers of the cuticle.

6. The *urine* is lessened in quantity. The urea is lessened, as shown by experiments in hot seasons at home and during voyages (Dr Forbes Watson and Dr Becher).[2] It is probable that this is simply from lessened food. The pigment has been supposed to be increased (Lawson), but this is doubtful. The chloride of sodium is lessened; the amount of uric and phosphoric acids is uncertain.

7. The effect on the *nervous* system is generally considered as depressing and exhausting, *i.e.*, there is less general vigour of mind and body. But it is undoubted that the greatest exertions both of mind and body have been made by Europeans in hot climates. Robert Jackson thought as much work could be got out of men in hot as in temperate climates. It is probable that the depressing effects of heat are most felt when it is combined with great humidity of the atmosphere, so that evaporation from the skin, and consequent lessening of bodily heat, are partly or totally arrested.[3]

The most exhausting effects of heat are felt when the heat is continuous, *i.e.*, very great, day and night, and especially in sandy plains, where the air is highly rarefied day and night. There is then really lessened quantity of oxygen in a given cubic space. Add to this fact that the respirations are lessened, and we have two factors at work which must diminish the ingress of oxygen, and thereby lessen one of the great agents of metamorphosis.

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1 *On Algide Cholera*, by E. A. Parkes, M.D., p. 14 (1847).

2 These experiments have never been fully published; they were made during voyages to Bombay and China, and show that when the temperature reached a certain point (75° in Dr Becher's experiments) the solids of the urine and the urea lessened considerably (*Proceedings of the Royal Society*, 1862).

3 See Dr Kenneth Mackinnon's *Treatise on Public Health*, p. 27, on the effect of plenty of exercise even in the hot, and moist, and presumed unhealthy climate of Tirhoot in Bengal. He proves that men can be much in the open air, even in the hot parts of the day, with impunity, and that when "they take exercise they are in the highest state of health." Still Dr Mackinnon believes the climate is exhausting.

S. Rattray made observations[1] on the *weight* and *height* of forty-eight naval cadets, aged from 14½ to 17 years, during four successive changes of climate during a voyage. The results show that in the tropics they increased in height more rapidly than in cold climates, but that they lost weight very considerably, and, in spite of their rapid growth, Rattray concludes that the heat impaired the strength, weight, and health of these lads. His figures seem conclusive on these points, and show the beneficial influence of cold on youths belonging to races long resident in temperate climates.

On the whole, even when sufficient perspiration keeps the body temperature within the limits of health, the effect of great heat in shade seems to be, as far as we can judge, a depressing influence lessening the nervous activity, the great functions of digestion, respiration, sanguification, and directly or indirectly the formation and destruction of tissues. Whether this is the heat alone, or heat and lessened oxygen, and great humidity, is not certain.

So bad have been the general and personal hygienic conditions of Europeans in India, that it is impossible to say what amount of the former great mortality in that country was due to excess of heat over the temperature of Europe. Nor is it possible to determine the influence of heat alone on the endemic diseases of Europeans in the tropics—liver disease and dysentery. There is, perhaps, after all, little immediate connection between heat and liver disease.

Rapid Changes of Temperature.—The exact physiological effects have not yet been traced out; and these sudden vicissitudes are often met by altered clothing, or other means of varying the temperature of the body. The greatest influence of rapid changes of temperature appears to occur when the state of the body in some way coincides with or favours their action. Thus, the sudden checking of the profuse perspiration by a cold wind produces catarrhs, inflammations, and neuralgia. It is astonishing, however, to find how well even phthisical persons will bear great changes of temperature, if they are not exposed to moving currents of air; and there can be little doubt that the wonderful balance of the system is soon readjusted.

SECTION II.

HUMIDITY.

According to their degree of humidity, climates are divided into moist and dry. Professor Tyndall's observations have shown how greatly the humidity of the air influences climate, by hindering the passage of heat from the earth. As far as the body is concerned, the chief effect of moist air is exerted on the evaporation from the skin and lungs, and therefore the degree of dryness or moisture of an atmosphere should be expressed in terms of the relative (and not of the absolute) humidity, and should always be taken in connection with the temperature, movement, and density of the air, if this last varies much from that of sea-level. The evaporating power of an atmosphere which contains 75 per cent. of saturation is very different, according as the temperature of the air is 40° or 80°. As the temperature rises, the evaporative power increases faster than the rise in the thermometer.

There is a general opinion that an atmosphere which permits free, without excessive, evaporation is the best; but there are few precise experiments.

The most agreeable amount of humidity to most healthy people is when the relative humidity is between 70 and 80 per cent. In chronic lung

[1] *Proceedings of the Royal Society*, No. 139.

diseases, however, a very moist air is generally most agreeable, and allays cough. The evaporation from the lungs produced by a warm dry atmosphere appears to irritate them. On the other hand, a still cold atmosphere is dry, without much capacity for holding moisture; so that the bracing effects of the cold are felt, without the irritation produced by too rapid evaporation from the respiratory surface. This may be one cause (among others) of the benefit derived in winter from such places as Davos, &c.

The moist hot siroccos, which are almost saturated with water, are felt as oppressive by man and beast; and this can hardly be from any other cause than the check to evaporation, and the consequent rise in the temperature of the body.

It is not yet known what rate of evaporation is the most healthy. Excessive evaporation, such as may be produced by a dry sirocco, is well borne by some persons, but not by all. Probably, in some cases, the physiological factor of perspiration comes into play, and the nerves and vessels of the skin are altered; and in this way perspiration is checked. We can hardly account in any other way for the fact that, in some persons, the dry sirocco, or dry hot land wind, produces harshness and dryness of the skin and general malaise, which possibly (though there is yet no thermometric proof) may be caused by a rise of temperature of the body.

From the experiments of Lehmann on pigeons and rabbits, it appears that more carbon dioxide is exhaled from the lungs in a very moist than in a dry atmosphere. The pathological effects of humidity are intimately connected with the temperature. Warmth and great humidity are borne on the whole more easily than cold and great humidity. Yet in both cases, so wonderful is the power of adaptation of the body that often no harm results.

The spread of certain diseases is supposed to be intimately related to humidity of the air. Malarious diseases, it is said, never attain their fullest epidemic spread unless the humidity approaches saturation. Plague and smallpox are both checked by a very dry atmosphere. The cessation of bubo plague in Upper Egypt, after St John's Day, has been considered to have been more owing to the dryness than to the heat of the air.

In the dry Harmattan wind, on the west coast of Africa, smallpox cannot be inoculated; and it is well known with what difficulty cowpox is kept up in very dry seasons in India. Yellow fever, on the other hand, seems independent of moisture, or will at any rate prevail in a dry air. The observations at Lisbon, which Lyons recorded, show no relation to the dew-point.

With regard to other diseases, and especially to diseases of sanguification and nutrition, observations are much needed.

SECTION III.

MOVEMENT OF AIR.

This is a very important climatic condition. The effect on the body is twofold. A cold wind abstracts heat, and in proportion to its velocity; a hot wind carries away little heat by direct abstraction, but, if dry, increases evaporation, and in that way may in part counteract its own heating power. Both, probably, act on the structure of the nerves of the skin and on the contractility of the cutaneous vessels, and may thus influence the rate of evaporation, and possibly affect also other organs.

The amount of the cooling effect of moving bodies of air is not easy to determine, as it depends on three factors, viz., the velocity of movement, the temperature, and the humidity of the air. The effect of movement is very

great. In a calm atmosphere an extremely warm temperature is borne without difficulty. In the Arctic expeditions calm air many degrees below zero of Fahr. caused no discomfort. But any movement of such cold air at once chills the frame. It has been asserted that some of the hot and very dry desert winds will, in spite of their warmth, chill the body; and if so, it can scarcely be from any other reason than the enormous evaporation they cause from the skin. It is very desirable, however, that this observation should be repeated, with careful thermometrical observations both on the body in the usual way and on the surface of the skin.

SECTION IV.

WEIGHT OF THE AIR.

Effects of Considerable Lessening of Pressure.

When the difference of pressure between two places is considerable, a marked effect is produced, and there seems no doubt that the influence of mountain localities is destined to be of great importance in therapeutics. It is of peculiar interest to the army surgeon, as so many regiments in the tropics are, or will be, quartered at considerable elevations.

In ascending mountains there is rarefaction, *i.e.*, lessened pressure of air; on an average (if the weight of the air at sea-level is 15 ℔ on every square inch) an ascent of 900 feet takes off $\frac{1}{2}$ ℔; but this varies with height; there are also lowered temperature and lessened moisture above 4000 feet, greater movement of the air, increased amount of light, greater sun radiation if clouds are absent; the air is freer from germs of infusoria; owing to the rarefaction of the air and lessened watery vapour, there is greater diathermancy of the air; the soil is rapidly heated, but radiates also fast, as the heat is not so much held back by vapour in the air, hence there is very great cooling of the ground and the air close to it at night.

The physiological effects of lessened pressure begin to be perceptible at 2800 or 3000 feet of altitude (= descent of $2\frac{1}{2}$ to 3 inches of mercury); they are—quickened pulse [1] (fifteen to twenty beats per minute); quickened respiration (increase = ten to fifteen respirations per minute), with lessened spirometric capacity,[2] increased evaporation from skin and lungs; lessened urinary water.[3] At great heights there is increased pressure of the gases in the body against the containing parts; swelling of superficial vessels, and occasionally bleeding from the nose or lungs. A sensation of weight is felt in the limbs from the lessened pressure on the joints. At altitudes under 6000 or 7000 feet the effect of mountain air (which is, perhaps, not owing solely to lessened pressure, but also, possibly, to increased light and pleasurable excitement of the senses) is to cause a very marked improvement in digestion, sanguification, and in nervous and muscular vigour.[4] It is inferred that tissue change is accelerated, but nothing definite is known.

The rapid evaporation at elevated positions is certainly a most important

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[1] *Balloon ascents.*—Biot and Gay-Lussac at 9,000 feet = incr. of 18 to 30 beats of the pulse.
Glaisher, . at 17,000 ,, = ,, 10 to 24 ,,
,, . at 24,000 ,, = ,, 24 to 31 ,,
The beats seem to augment in number with the elevation. These are safer numbers than those obtained in mountain ascents, as there is no physical exertion. In mountain climbing the increase is much greater.

[2] Rattray found an ascent of 2000 feet (at Ascension) lessened the "vital capacity," as judged of by the spirometer, from 266 to 249 and 243 cubic inches.

[3] Vivenot, *Virchow's Archiv,* 1860, Band xix. p. 492. This is probable, but not yet proved.

[4] Hermann Weber, *Climate of the Swiss Alps,* 1864, p. 17.

element of mountain hygiene. At Puebla and at Mexico the hygrometer of Saussure will often mark 37°, which is equal to only 45 per cent. of saturation,[1] and yet the lower rooms of the houses are very humid, so that in the town of Mexico there are really two climates,—one very moist, in the *rez-de-chaussée* of the houses; one very dry, in the upper rooms and the outside air.

The diminution of oxygen, in a certain cubic space, is precisely as the pressure, and can be calculated for any height, if the barometer is noted. Taking dry air only, a cubic foot of air at 30 inches, and at 32° Fahr., contains 130·4 grains of oxygen. An ascent (about 5000 feet) which reduces the barometer to 25 inches will lessen this $\frac{1}{6}$th, or $\left(\frac{25 \times 130{\cdot}4}{30} = \right)$ 108·6 grains. But it is supposed that the increased number of respirations compensates, or more so, for this; and, in addition, it must be remembered that in experiments on animals, as long as the percentage of oxygen did not sink below a certain point (14 per cent.), as much was absorbed into the blood as when the oxygen was in normal proportion. Jourdanet has indeed asserted[2] that the usual notion that the respirations are augmented in number in the inhabitants of high lands is "completely erroneous"; that the respirations are in fact lessened, and that from time to time a deeper respiration is voluntarily made as a partial compensation. But Coindet, from 1500 observations on French and Mexicans, does not confirm this; the mean number of respirations was 19·36 per minute for the French, and 20·297 for the Mexicans.

As a curative agent, mountain air (that is, the consequences of lessened pressure chiefly) ranks very high in all anæmic affections from whatever cause (malaria, hæmorrhage, digestive feebleness, even lead and mercury poisoning); and it would appear, from Hermann Weber's observations, that the existence of valvular heart disease is, if proper rules are observed, no contradiction against the lower elevations (2000 to 3000 feet). Neuralgia, gout, and rheumatism are all benefited by high Alpine positions (H. Weber). Scrofula and consumption have been long known to be rare among the dwellers on high lands, and the curative effect of such places on these diseases is also marked; but it is possible that the open-air life which is led has an influence, as it is now known that great elevation is not necessary for the cure of phthisis.[3]

Dr Hermann Weber, in his important work on the Swiss Alps (p. 22), has given the present evidence, and has shown how in the true Alpine region—in Dauphiné, in Peru and Mexico, and in Germany—phthisis is decidedly averted or prevented by high altitudes. The more recent experience of Davos Platz is confirmatory.

Although on the Alps phthisis is arrested in strangers, in many places the Swiss women on the lower heights suffer greatly from it; the cause is a social one: the women employed in making embroidery congregate all day in small, ill-ventilated, low rooms, where they are often obliged to be in a constrained position; their food is poor in quality. Scrofula is very common. The men, who live an open-air life, are exempt; therefore, in the very place

[1] Jourdanet, *Du Mexique*, p. 49.

[2] *Du Mexique*, p. 76.

[3] Some time ago a remarkable paper was published by Dr James Blake, of California, on the treatment of phthisis (*Pacific Medical Journal*, 1860). He adopted the plan of making his patients live in the open air; in the summer months he made them sleep out without any tent: the result was an astonishing improvement in digestion and sanguification; the resistance to any ill effects from cold and wet is described as marvellous. As Dr Blake is well known to be perfectly trustworthy, these statements are worthy of all consideration.

where strangers are getting well of phthisis the natives die from it—another instance that we must look to local conditions and social habits for the great cause of phthisis. It would even seem possible that, after all, it is not indeed elevation and rarefaction of air, but simply plenty of fresh air and exercise which are the great agents in the cure of phthisis.

Jourdanet, who differs from so much that is commonly accepted on this point, gives additional evidence on the effect of elevation on phthisis. At Vera Cruz phthisis is common; at Puebla and on the Mexican heights it is almost absent (*à peu près nulle*).

The diseases for which mountain air is least useful are—rheumatism, at the lower elevations where the air is moist; above this rheumatism is improved; and chronic inflammatory affections of the respiratory organs (?). The "mountain asthma" appears, however, from Weber's observations, to be no specific disease, but to be common pulmonary emphysema following chronic bronchitis.

It seems likely that pneumonia, pleurisy, and acute bronchitis are more common in higher Alpine regions than lower down.

Effects of Increased Pressure.—The effects of increased pressure have been noticed in persons working in diving-bells, &c., or in those submitted to treatment by compressed air. (At Lyons and at Reichenhall[1] especially.) When the pressure is increased to from $1\frac{1}{4}$ to 2 atmospheres, the pulse becomes slower, though this varies in individual cases; the mean lessening is 10 beats per minute; the respirations are slightly lessened (1 per minute); evaporation from the skin and lungs is said to be lessened (?); there is some recession of blood from the peripheral parts; there is a little ringing and sometimes pain in the ears; hearing is more acute; the urine is increased in quantity; appetite is increased; it is said men will work more vigorously. When the pressure is much greater (two or three atmospheres) the effects are sometimes very marked; great lowering of the pulse, heaviness, headache, and sometimes, it is said, deafness. It is said[2] that more oxygen is absorbed, and that the venous blood is as red as the arterial; the skin also sometimes acts more, and there may even be sweating. The main effect is to lessen the quantity of blood in the veins and auricles, and to increase it in the arteries and ventricles; the filling of the ventricle during the relaxation takes place more slowly. The diastolic interval is lengthened, and the pulse is therefore slower.

When the workmen leave the compressed air they are said to suffer from hæmorrhages and occasional nervous affections, which may be from cerebral or spinal hæmorrhage.[3] As a curative agent in phthisis, the evidence is unfavourable.

Some observations made by M. Bert[4] show that oxygen, when it enters the blood under pressure (such as that given by 17 atmospheres of atmospheric air, or $3\frac{1}{2}$ atmospheres of pure oxygen), is toxic to birds, producing convulsions. Convulsions are produced in dogs when the pressure is only 7 or 8 atmospheres and when the oxygen amounts to only double the normal amount, or, in other words, reaches 32 c.c. per 100 c.c. of blood. M. Bert conjectured that the toxic influence of oxygen was on the nervous centres, like strychnine. The animal temperature fell 2 or 3 degrees (C.) during the convulsions, so that excess of oxygen did not cause increased

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[1] For an account of the effects noted at Reichenhall, see Dr Burdon-Sanderson's account in *The Practitioner*, No. iv. 1868, p. 221.

[2] Foley, "Du Travail dans l'air comprimé," *Gaz. Hebdom.*, 1863, No. 32.

[3] See Limousin, in *Canstatt*, 1863, Band ii. p. 105, and Babington in *Dublin Quarterly Journal*, Nov. 1864.

[4] *Chemical News*, March 28, 1873.

combustion. In the case of a dog kept under a pressure of 9½ atmospheres for some time, gas was found in the ventral cavity and in the areolar tissue. In man the pressure of only 5 atmospheres appears to be dangerous.[1]

Is Acclimatisation possible?

The doctrine of acclimatisation has been much debated, but probably we do not know sufficiently the physiological conditions of the body under different circumstances. In the case of Europeans living till puberty in a temperate region, near the sea-level, and in a moist climate like England, and then going to the tropics, the question of acclimatisation would be put in this form,—Does the body accommodate itself to greater heat, to lessened humidity in some cases, or greater in others, and to varying altitudes?

There can be little doubt that the body does accommodate itself within certain limits to greater heat, as we have seen that the lungs act less, the skin more, and that the circulation lessens when Englishmen pass into the tropics. There is so far an accommodation or alteration impressed on the functions of the body by unwonted heat. And we may believe that this effect is permanent, *i.e.*, that the lungs continue to act less and the skin more, as long the Europeans remain in the tropics. Doubtless, if the race were perpetuated in the tropics, succeeding generations would show fixed alterations in these organs.

We may conclude that the converse holds true, and that the cold of temperate regions will influence natives of the tropics in an opposite way, and this seems to be rendered likely by the way in which lung affections arise in many of them.

We may admit there is an acclimatisation in this sense, but in no other. The usual belief that the constitution acquires in some way a power of resisting unhealthy influences—that is, a power of not being any longer susceptible to them—is not supported by any good evidence. The lungs in Europeans will not regain their weight and amount of action in the tropics; a change to a cold climate only will cause this; the skin retains its increased function until the cause producing it is removed. So also there is no acclimatisation in any sense of the word for malaria.

SECTION V.

COMPOSITION OF THE AIR.

The proportionate amounts of oxygen and nitrogen remain very constant in all countries, and the range of variation is not great.

So also, apart from the habitations of men, the amount of carbon dioxide is (at elevations occupied by men) constant. The variations in watery vapour have been already noticed.

The only alterations in the composition of the air which come under the head of climate are changes in the state in which oxygen exists (for no change is known to occur in nitrogen), and the presence of impurities.

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[1] In the colliery accident at Pont-y-Prydd, several men were confined for ten days in a small space, in which the air was much compressed. The exact pressure is unknown, but it was sufficient to drive one of the men, with fatal force, into the opening made for their rescue. Although tho men were without food all the time, they appeared to have suffered less than might have been anticipated.

Sub-Section I.—Ozone.

Ozone is now admitted by most chemists to be an allotropic condition of oxygen; and, as conjectured by Odling, it is now believed that it is a compound molecule made up of three molecules (O_2O) of oxygen. The so-called antozone is now believed to be peroxide of hydrogen diffused in a large quantity of atmospheric air. Variations in the amount of ozone have been supposed to be a cause of climatic difference, but, in spite of all the labour which has been given to this subject, the evidence is very inconclusive. The reaction with the ozone paper is liable to great fallacies.[1] Yet it seems clear that some points are made out: the ozonic reaction is greater in pure than impure air; greater at the sea-side than in the interior; greater in mountain air than in the plains; absent in the centre of large towns, yet present in the suburbs; absent in an hospital ward, yet present in the air outside. In this country it is greater with south and west winds; greater, according to Moffat, when the mean daily temperature and the dew-point temperature are above the mean; the same observer found it in increased quantity with decreasing readings of the barometer, and conversely in lessened quantity with increasing readings.

The imperfections in the test render it desirable to avoid drawing conclusions at present; but one or two points must be adverted to.

1. Owing probably to the oxidising power of ozone when prepared in the laboratory, a great power of destruction of organic matter floating in the air has been ascribed to ozone by Schönbein, and the absence of ozone in the air has been attributed by others to the amount of organic matter in the air of towns. Even the cessation of epidemics (of cholera, malarious fevers) has been ascribed to currents of air bringing ozone with them. The accumulation of malaria at night has been ascribed to the non-production of ozone by the sun's rays (Uhle). The effect of stagnant air in increasing epidemics has also been ascribed to the absence of ozone.

It seems clear that the substance giving the reaction of ozone is neither deficient in marshy districts, nor, when ozone is conducted through marsh dew, does it destroy the organic matter.[2]

2. On account of the irritating effect of ozone when rising from an electrode, Schönbein believed it had the power of causing catarrh, and inferred that epidemics of influenza might be produced by it. He attempted to adduce evidence, but at present it may safely be said that there is no proof of such an origin of epidemic catarrhs.

3. A popular opinion is, that a climate in which there is much ozone (*i.e.*, of the substance giving the reaction with potassium iodide and starch paper) is a healthy, and, to use a common phrase, an exciting one. The coincidence of excess of this reaction with pure air lends some support to this, but, like the former opinions, it still wants a sufficient experimental basis.

On the whole, the subject of the presence and effects of ozone, curious and interesting as it is, is very uncertain at present; experiments must be numerous, and inferences drawn from them must be received with caution.

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[1] The subject of ozone will be found fully discussed by Dr C. Fox (*Ozone and Antozone*, 1873). The causes of fallacy in the tests are carefully explained.

[2] In addition to what has been previously said (p. 150), Grellois has stated that he found more ozone over a marsh than elsewhere. An interesting series of observations on ozone in the Bombay Presidency has been made by Dr Cook.

Sub-Section II.—Malaria.

The most important organic impurity of the atmosphere is malaria, and when a climate is called "unhealthy," in many cases it is simply meant that it is malarious. In the chapters on Soils and Air the most important hygienic facts connected with malaria have been noted. In this place it only remains to note one or two of the climatic points associated with malaria.

1. *Vertical Ascent.*—A marsh or malarious tract of country existing at any point, what altitude gives immunity from the malaria, supposing there is no drifting up ravines? It is well known that even a slight elevation lessens danger—a few feet even, in many cases, but complete security is only obtained at greater heights. Low elevations of 200 or 300 feet are often, indeed, more malarious than lower lands, as if the malaria chiefly floated up.

At present the elevation of perfect security in different parts of the world is not certainly determined, but appears to be—

Italy, ...	400 to 500 feet.[1]
America (Appalachia), . .	3000 ,,
California,[2]	1000 ,,
India, ...	2000 to 3000 ,,
West Indies, . . .	1400 ,, 1800 up to 2200 feet.

But these numbers are so far uncertain that it has not always been seen that the question is not, whether marshes can exist at these elevations (we know they can be active at 6000 feet), but whether the emanations from a marsh will ascend that height without drifting up ravines? 1000 to 1200 feet would generally give security in all probability.

2. *Horizontal Spread.*—In a calm air Lévy[3] has supposed that malaria will spread until it occupies a cube of 1400 to 2000 feet, which is equivalent to saying it will spread 700 to 1000 feet horizontally from the central point of the marsh. But currents of air take it great distances, though the best observations show that these distances are less than were supposed, and seldom overpass one or two miles, unless the air-currents are rapid and strong. The precise limits are unknown, but it is very doubtful if the belief in transference of malaria by air-currents for 10, 20, or even 100 miles, is correct.

3. *Spread over Water.*—The few precise observations show that this differs in different countries. In the Channel, between Beveland and Walcheren, 3000 feet of water stopped it (Blane). In China and the West Indies a farther distance is necessary. In China three-quarters of a mile has been effectual;[4] in the West Indies one mile. Grant thinks that salt water is more efficacious than fresh.

SECTION VI.

ELECTRICAL CONDITION—LIGHT.

That these, as well as heat, are important parts of that complex agency we call Climate, seems clear; but little can be said on the point. In hot

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1 Carrière, quoted by Lévy, t. i. p. 491.
2 This information was given by Dr James Blake.
3 T. i. p. 464.
4 Grant (quoted by Chevers), *Indian Annals*, 1859, p. 636.

countries positive electricity is more abundant; but the effect of its amount and variation on health and on the spread and intensity of diseases is quite unknown. All that has been ascribed to it is pure speculation. The only certain fact seems to be that the spread of cholera is not influenced by it.

With regard to light, the physiological doctrine of the necessity of light for growth and perfect nutrition makes us feel sure that this is an important part of climate, but no positive facts are known.

CHAPTER XVI.

DESCRIPTION OF THE METEOROLOGICAL INSTRUMENTS, AND A FEW REMARKS ON METEOROLOGY.

As meteorological observations are now so commonly made, and as in the army instruments are provided at many foreign stations, it is desirable to give a few plain instructions on the use of these instruments.[1] For the convenience of beginners, a few observations on Meteorology are also added.

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[1] The following is the official circular issued by the Army Medical Department:—

Official Instructions for reading the Meteorological Instruments.

The observer should make himself thoroughly acquainted with the scale of every instrument, especially with that of the barometer and its attached vernier, and by frequent comparisons ascertain that he and his deputy read the instruments alike, and record the observations accurately.

All observations must be recorded exactly as read. The corrections are to be made only at the end of each month on the "means" of the "sums."

Barometrical observations must be recorded to the third decimal place; thermometrical to the first decimal. When the readings are exactly to the inch or degree, the places for the decimals must be filled up with ciphers.

The observations should be made as quickly as possible, consistent with perfect accuracy, and the observer must avoid breathing on the instruments, particularly the dry and wet bulb and maximum thermometers.

Barometer Readings.—Note the temperature of attached thermometer in degrees only; by means of the thumb-screw at the bottom adjust the mercury in the cistern to its proper level, – the point of the ivory cone, which should just touch the mercury without breaking the surface; then bring the zero line of the vernier to the level of the apex of column of the mercury, and read off in the manner described at pages 15 and 16 of Sir H. James's Book of Instructions.[1]

Thermometer Readings.—The scales are divided to degrees only, but these are so open that the readings can be determined to the tenth of a degree. Practice and attention will insure accuracy.

Maximum Thermometer in Shade.—The maximum thermometer must be hung at such a distance (2 or 3 inches) from the water vessel of the wet-bulb thermometer that its readings may not be affected by evaporation.

In hanging the maximum, care must be taken that the end of the tube is *slightly inclined downwards*, which will have the effect of assisting in preventing the return of any portion of the column of mercury into the bulb on a decrease of temperature. To read the instrument, gently elevate the end furthest from the bulb to an angle of about 45°, in which position of the instrument note the reading.[2] To re-set the thermometer, a gentle shake or swing, or a tap on the wooden frame of the instrument, will cause the excess of mercury to return to the bulb, and it is again ready for use.

Maximum in Sun's Rays, or the Vacuum Solar Radiation Thermometer.—Being constructed on the same principle as the last-mentioned instrument, it must be read in a similar position. After completing the reading, by giving the instrument a slight shake, with the bulb still inclined downwards, the excess of mercury will return to the bulb, and the thermometer be ready for the next observation.

Minimum Thermometer in Shade.—The minimum thermometer must be so hung that the bulb may be about *one inch lower* than the other extremity of the instrument, because in this position the index is less likely to be affected by a rise in temperature.

The extremity of the index furthest from the bulb shows the lowest degree to which the spirit has fallen since the last observation. The reading on the scale corresponding to this is the temperature to be recorded. Then by elevating the bulb, the index will float towards the end of the spirit. When it has *nearly arrived at that point*, the instrument is re-set.

Minimum on Grass, Terrestrial Radiation Thermometer is constructed like the last, and the directions above given are also applicable to it.

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[1] For these are now substituted *Instructions on the Use of Meteorological Instruments*, by R. H. Scott, M.A., F.R.S., 1877. The Barometer corrections are explained at pp. 30, 31 of that work.

[2] The instrument had better be read as it is on the stand, because with a comparatively widely calibred tube the above instruction might lead to the mercury flowing backwards, and so giving an erroneous reading.

SECTION I.

THERMOMETERS FOR TAKING THE TEMPERATURE OF THE AIR.

Maximum Thermometers.

Two maximum thermometers are issued—one to observe the greatest heat in the sun, the other in the shade.

The *Sun Maximum* or *Solar Radiation Thermometer* is formed by a glass case (from which the air is removed), containing a mercurial thermometer with a blackened bulb. The case shelters from currents of air; the black bulb absorbs the sun's rays. The tube of the thermometer is slightly bent near the bulb, and a piece of porcelain is inserted which narrows the tube. The effect of this is to make the thermometer self-registering, as, after the mercury has expanded to its fullest extent, instead of retiring into the bulb on cooling, it is stopped by the porcelain, and the mercury breaks between the porcelain and the bulb. The instrument is placed at a height of four feet from the ground on wooden supports, and in any place where the sun's rays can fall freely on it.

The *Shade Maximum* is a mercurial thermometer, not inclosed in a case, but mounted on a frame. Its construction and manner of reading are otherwise similar to those of the sun thermometer.

It is placed in the shade four feet above the ground, and sufficiently far from any walls to be unaffected by radiation. It should be freely exposed to the air, but perfectly protected from the sun's rays.

After reading and re-setting the self-registering thermometers, compare them with the dry-bulb thermometer in order to ascertain that their readings are nearly the same.

Dry- and Wet-Bulb Thermometers.—Bring the eye on a level with the top of the mercury in the tube of the dry-bulb thermometer, and take the reading, then complete the observation by noting in like manner the reading of the wet-bulb thermometer.

The temperature of the air is given by the former, that of evaporation by the latter. From these data hygrometrical results are to be calculated by Glaisher's Tables, 3rd edition.[1]

Rain-Gauge and Measure.—Pour the contents of the gauge into any convenient vessel with a lip, and from this into the glass measure, which has been graduated especially for the gauge, and is only to be used in measuring its contents. It is graduated to the hundredths of an inch.

Anemometers.—The dials are read from left to right. The first on the left records hundreds of miles, the second tens, the third miles, the fourth tenths of a mile, and the fifth hundredths of a mile.

The reading of the anemometer is obtained by deducting from the amount registered by the dials the total sum registered at the period of the preceding observation. The difference between those (subject to a small correction) indicates the velocity or horizontal movement of the air in miles during the interval, and must be entered in the return. When the instrument is first set up, the reading on the dials must be noted, in order that it may be deducted from the total registered by the dials at the end of the first period of observation.

In making observations on the presence of ozone, a box has been found to be unnecessary, equally satisfactory results having been obtained by fixing the paper immediately under the penthouse of the stand, which shelters it sufficiently from a strong light, while it secures proper exposure.

The minimum thermometers are liable to get out of order—first by carriage, when the index may be wholly or partly driven out of the spirit, or a portion of spirit may become detached from the main column; and, secondly, by slow evaporation of the spirit, which, rising in the tube, condenses at the upper end. The first-mentioned errors are corrected by taking the thermometer in the hand, with its bulb downwards, and giving it a swing up and down. The second is remedied by the inclined position of the instrument, which allows the condensed spirit to trickle back to the main column.[2]

N.B.—On no account whatever is artificial heat to be applied to a spirit thermometer. In re-setting the minimum, the index should never be brought quite to the end of the column of spirit.

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[1] A 6th edition is now published.

[2] It is generally necessary to swing the instrument to get back the broken portion of the column.

Minimum Thermometers.[1]

Two minimum thermometers are supplied.

The *Shade Minimum* is an alcoholic thermometer with a small index in the alcohol. It is set by allowing the index to slide *nearly* to the end of the spirit; as the spirit contracts during cold, it carries the index down; when it expands again it cannot move the index, but leaves it at the degree of greatest cold. The end of the index farthest from the bulb is the point to read.

This thermometer is placed in the shade four feet above ground, under the same conditions as the *shade maximum.*

The *Grass Minimum* or *Terrestrial Radiation Thermometer* is a thermometer of the same kind, but protected by a glass shield. It is placed almost close to the ground on grass, suspended on little trestles of wood, but it should not touch the ground; it is intended to indicate the amount of cooling produced by radiation from the ground. If snow lies on the ground the bulb should be placed in the snow. Scott recommends a black board on which to lay the thermometer where no grass can be obtained.[2]

Common Thermometer.

The dry bulb of the "wet and dry bulb thermometer" is read as a common thermometer.

Reading of the Thermometers.

All these thermometers can be read, by the eye, to tenths of a degree. The maximum and minimum thermometers are read once a day, usually at 9 A.M.; the former marks the highest point reached on the *previous* afternoon, and must be so entered on the return; the latter, the lowest point reached on the *same* morning.[3] For the army returns the common thermometer is read twice a day, at 9 A.M. and 3 P.M.

Range of the Temperature.—The maximum and minimum in shade give most important climatic indications; the difference between them on the same day constitutes the range of the diurnal fluctuation. The range is expressed in several ways.

The extreme daily range in the month or year is the difference between the maximum and minimum thermometer on any one day.

The extreme monthly or annual range is the difference between the greatest and least height in the month or year.

The mean monthly range is the daily ranges added and divided by the number of days in a month (or between the mean of all the maxima and the mean of all the minima).

The yearly mean range is the monthly ranges added and divided by 12.

Mean Temperature.—The mean temperature of the day is obtained in the following ways:—

(*a*) At Greenwich and other observatories, where by means of photography

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[1] Great difficulty is found with spirit thermometers on account of their being so much less sensitive than mercurial. To remedy this the bulb is sometimes made fork-shaped, or otherwise modified so as to expose as large a surface as possible.

[2] *Instructions*, &c. Scott adds: "Under any circumstances, a board gives a better measure of terrestrial radiation than grass."

[3] It is desirable that these thermometers should be read both morning and evening. In winter the maximum sometimes occurs in the early morning and the minimum in the afternoon, and the range depends more on the direction of the wind than on the time of day (Scott). But uniformity of practice is the primary essential, and at stations where observations are made only once a day, viz., at 9 A.M., or even twice, unless the second reading is after 6 P.M., the above rule as to entry must be followed.

the height of the thermometer at every moment of the day is registered, the mean of the hourly readings is taken. This has been found to accord with the absolute mean (found by taking the mean of the whole curve) to within $\frac{1}{10}$th of a degree.

(*b*) Approximately in several ways. Taking the mean of the shade maximum and minimum of the same day. In this country, during the cold months (December and January), the result is very close to the truth; but as the temperature increases a greater and greater error is produced, until in July the mean monthly error is $+1^\circ \cdot 9$ Fahr., and in some hot days is much greater. In the tropics, the mean of the maximum and minimum must give a result still further from the truth.

Monthly corrections can be applied to bring these means nearer the truth. Mr Glaisher's corrections for this country are as follows :—

Subtract from the monthly mean of the maximum and minimum—

January,	0°·2	May,	1°·7	September,	1°·3
February,	0·4	June,	1·8	October,	1·0
March,	1·0	July,	1·9	November,	0·4
April,	1·5	August,	1·7	December,	0·0

The result is the approximate mean temperature. But this is true only for this country.[1]

In a great number of places the mean temperature of the day and year, as stated in books, is derived solely from the mean of the maximum and minimum.[2] According to Scott, the approximation to the true mean is very close in most parts of the world, especially if the observations be taken as near the *end* of the period as possible, near midnight, for instance, for the mean of the civil day of twenty-four hours.

The approximate mean temperature may also be obtained by taking observations at certain times during the day, and applying a correction. Mr Glaisher has given some very valuable tables of this kind,[3] which can be consulted.[4]

If the temperature be taken twice a day at homonymous hours, such as 9 A.M. and 9 P.M., the mean of these does not differ much from the true daily mean (Scott).

The nearest approach to the mean temperature of the day by a single observation is given at from 8 to 9 P.M.; the next is in the morning—about 8 o'clock in July and 10 in December and January.

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[1] These numbers of Mr Glaisher are likely to be modified very considerably; they are largely dependent on the pattern of the thermometer stand employed.

[2] With a Stevenson's screen the simple mean of the maximum and minimum is very near the truth.

[3] *On the Corrections to be applied to Meteorological Observations for Diurnal Range*, prepared by the Council of the British Meteorological Society, 1850. These corrections are applicable only to this country.

[4] The following rules, which are applicable in all parts of the world, are given by Herschel:[1]—

If observations are taken three times daily—at 7 A.M., 2 P.M., and 9 P.M.,—hours which we may denote by t, t', and t''; then

$$\frac{t+t'+2\,t''}{4} = \text{mean temperature of day.}$$

If the hours are 8 A.M., 3 P.M., and 10 P.M., the formula is—

$$\frac{7\,t+7\,t'+10\,t''}{24} = \text{mean of day.}$$

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[1] *Meteorology*, p. 173.

The nearest approach to the mean annual temperature is given by the mean of the month of October. Observations made from a week before to a week after the 24th April, and again in the corresponding weeks of October, give a certain approximation to the yearly mean temperature.[1]

The changes in temperature of any place, during the day or year, are either periodic or non-periodic. The former are dependent on day and night, and on the seasons, *i.e.*, on the position of the place with respect to the sun. The periodic changes are sometimes termed fluctuations, and the differences between day and night temperatures, or the temperatures of the hottest and coldest months, are often called the amplitudes of the daily or yearly fluctuations.

Daily Periodic Changes.—On land the temperature of the air is usually at its lowest about 3 o'clock A.M., or just before sunrise, and at its maximum about 2 o'clock P.M.; it then falls nearly regularly to 3 o'clock A.M. At sea, the maximum is nearly an hour later.

The amount of diurnal periodic change is greater on land than on water; in the interior of continents than by the sea-side; in elevated districts than at sea-level. As far as land is concerned, it is least on the sea-coast of tropical islands, as at Kingston in Jamaica, Colômbo in Ceylon, Singapore, &c.

Yearly Periodic Changes.—In the northern hemisphere, the coldest month is usually January; in some parts of Canada it is February. On the sea, the coldest month is later, viz., March. The hottest month is in most places July, in some few August; on the sea it is always August. The coldest days in this country are towards the 21st January; the hottest, about the 18th to the 21st July. At Toronto the hottest day is 37 days after the summer solstice; and the coldest 55 days after the winter solstice.

It is thus seen that both for the diurnal and annual alterations of heat the greatest heat is not simultaneous with, but is after, the culmination of the sun; this is owing to the slow absorption of heat by the earth.

The amplitude of the yearly fluctuation is greater on land than sea, and is augmented by land, so that it reaches its highest point in the interior of great extra-tropical continents.

It increases towards the pole for three reasons,—

1. The geographical fluctuation of the earth's position causes a great yearly difference of the angle with which the sun's rays fall on the earth.

2. The duration of incidence of the sun's rays (*i.e.*, the number of hours of sunshine or shade) have greater yearly differences than in the tropics.

3. In the northern hemisphere especially there is a very great extent of land, which increases radiation.

The amplitude of the yearly fluctuation is very small in the tropical lands at sea-level. At Singapore it is only 3°·6 Fahr. (Jan. 78°·8, July 82°·4), while it is immense on continents near the pole. At Jakoutsk, in North Asia, it is 112°·5 (January $-44°·5$ and July $+68$). All fluctuations depend to a large extent upon the distance from the sea, although local causes may have some influence, such as the vicinity of high lands.

In any place there may be great undulations and small fluctuations, or great changes in each way. At Brussels, the greatest possible yearly undulation is 90°. In some parts of Canada immense undulations sometimes occur in a day, the thermometer ranging even 50° to 70° in one day.

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[1] Herschel, *Meteorology*, p. 180.

The hot winds of the rainless deserts have long puzzled meteorologists; they often cause enormous undulations, 50° to as much as 78° Fahr.

Temperature of the Air of any Place.

This depends on the following conditions:—

1. *Geographical Position as influencing the Amount and Duration of Sun's Rays which are received.*—The nearer the equator the hotter. For $23\frac{1}{2}°$ on either side the equator the sun's rays are vertical twice in the year, and are never more oblique than 47°. The mean yearly temperature of the equator is 82° Fahr.; of the pole about 2°·5 Fahr. The decline from the equator to the pole is not regular; it is more rapid from the equator to 30 than in the higher latitudes.

2. *Relative Amount of Land and Water.*—The sun's rays passing through the air with but trifling loss fall on land or on water. The specific heat of land being only one quarter that of water, it both absorbs heat and gives it out more rapidly. Water, on the other hand, absorbs it more slowly, stores up a greater quantity, and parts with it less readily. The temperature of the superficial water, even in the hottest regions, seldom exceeds 80° to 82°, and that of the air is generally below (2° to even 6°) the temperature of the water (J. Davy). Consequently the more land the greater is the heat, and the wider the diurnal and yearly amplitudes of fluctuation. The kind of soil has a great effect on absorption. The evaporation from the water also greatly cools the air.

3. *Elevation of the Place above the Sea-Level.*—The greater the elevation the colder the air, on account—1*st*, of the lessening amount of earth to absorb the sun's rays; and, 2*nd*, on account of the greater radiation into free space. The decline of temperature used to be reckoned at about 1° Fahr. for each 300 feet of ascent, but the balloon ascents of Mr Welsh, and especially of Mr Glaisher, have proved that there is no regular decline; there are many currents of warm air even in the upper atmosphere. Still the old rule is useful as an approximation. The amount of decline varies, however, in the same place at different times of the year. In Mr Glaisher's balloon ascents, in a *cloudy* sky, it was about 4° Fahr. for each inch of barometric fall, at first; but when the barometer had fallen 11 inches, the decline of temperature was more rapid. Under a *clear* sky, there was a fall of 5° Fahr. for each of the first four inches of descent: then 4° per inch till the thirteenth inch of descent, and then 4°·5 for fourteenth, fifteenth, and sixteeth inches of descent.

The snow-line at any spot, or the height at which snow will lie the whole year, can be approximately reckoned by taking the mean yearly temperature of the latitude at sea-level, and multiplying the difference between that temperature and 32° Fahr. by 300. The aspect of a place, however, the distance from the sea, and other circumstances, have much to do with the height of the permanent snow-line. The mean temperature of any place can be approximately reckoned in the same way, if the mean temperature of the latitude at sea-level, and the elevation of the place in feet, be known.

4. *Aspect and Exposure, and Special Local Conditions.*—These circumstances chiefly affect a place by allowing free exposure to or sheltering from the sun's rays, therefore lessening the number of hours the rays reach the soil, or by furnishing at certain times a large moist surface. Thus the extensive sandbanks of the Mersey cause very rapid alterations of temperature in the water and air, by being exposed every twenty-four hours twice to the sun and sky (Adie).

5. *Aërial and Ocean Currents.*—These have a great effect, bringing clouds which block out the sun or produce rain, or which, in the case of ocean currents, cool or warm the air. The cold polar sea currents and the warm equatorial (like the Gulf Stream) in some cases almost determine, and always greatly influence, the temperature.

6. *Nature of the Soil.*—On this point little is yet known, but it is certain that some soils easily absorb heat; others do not. The moist and clayey soils are cold; the dry hard rocks and dry sands are hot.

The hottest places on the earth are—in the eastern hemisphere, near the Red Sea, at Massava and Khartoum (15° N. lat.), and on the Nile in Lower Nubia; annual temperature = 90°·5 Fahr.; in the western hemisphere, on the Continent, near the West Indies, the annual temperature is 81°·5. These are sometimes called the climatic poles of heat. The poles of cold are in Siberia (Jakoutsk to Usjausk, 62° N.), and near Melville Island.

Isothermal Lines.—These are lines drawn on charts, and were proposed by Humboldt to connect all places having the same mean annual temperature. The various conditions just noted cause these lines to deviate more or less from the lines of latitude.

The lines of mean summer temperature (three months, June, July, August) are sometimes called *isotheral;* those of mean winter temperature (December, January, and February) *isocheimonal*, or *isocheimal*, but those terms are now seldom used, the terms summer, winter, or monthly *isothermal* being substituted.[1]

SECTION II.

HYGROMETERS—HUMIDITY OF THE AIR.

The amount of watery vapour in the air can be determined in several ways,—by direct weighing, by Daniell's, Regnault's, or Dines' hygrometer, by the hair hygrometers of Saussure and Wolpert, and by the dry and wet bulbs.[2] The method by the dry and wet bulb thermometers has been adopted by the Army Medical Department, and observations are taken twice daily (9 A.M. and 3 P.M.). The instruments are not self-registering, and are simply read off. They are placed in the shade, four feet above the ground, the bulbs freely exposed to the air, but not exposed to the effect of radiant heat from brick walls, &c. The wet bulb is covered with muslin, which is kept moistened by cotton twisted round the bulb and then passing into the water vessel; previous to use, the cotton is soaked in solution of carbonate of soda, or boiled in ether to free it from fat, so that water may ascend easily in it by capillary attraction; the muslin and cotton should be renewed frequently, once or twice a month if possible; the water must be either rain or distilled water, and the supply ought to be more ample in dry hot weather than in damp. When the temperature is below the freezing-point, the passage of water along the cotton is arrested; it is then necessary to moisten

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[1] It may be well to mention the relations between the three principal thermometer scales. Whilst the freezing-point in the Fahrenheit scale is at 32° it is at 0° in both the Centigrade (or Celsius) and the Réaumur scales. Water boils at 212° on the Fahrenheit scale (barometer=29·905), at 100° on the Centigrade, and at 80° of Réaumur.

Hence the formula of reduction is—

$$\frac{F-32}{9}=\frac{C}{5}=\frac{R}{4},$$

from which the corresponding temperatures can be easily found.

[2] These last are to be considered as one instrument, and are frequently called the Psychrometer of August, or (in this country) of Mason.

the wet bulb some time before the hour of observation, so as to allow the moisture to freeze. The *dew-point*, the *weight of a cubic foot of vapour*, and the *relative humidity*, are to be computed from Mr Glaisher's tables.[1]

Definition of these Terms. —The *dew-point* is the temperature when the air is just saturated with moisture, so that the least cooling would cause a deposit of water. The quantity of vapour which can be taken up and be made quite invisible to the senses varies with temperature, and is called the *weight of a cubic foot of vapour*, or, less accurately, the *weight of vapour in a cubic foot of air*, at the particular temperature.

The dew-point may be obtained *directly* by Daniell's, or Regnault's, or Dines' hygrometer, which enable us to cool and note the temperature of a bright surface until the dew is deposited on it, or *indirectly* by means of the dry and wet bulbs.

Unless the air is saturated, the temperature of the wet bulb (*i.e.*, the temperature of evaporation) is always above the dew-point, but is below the temperature of the dry bulb, being reduced by the evaporation. If the dry and wet bulbs are of the same temperature, the air is saturated with moisture, and the temperature noted is the dew-point; if they are not of the same temperature, the dew-point is at some distance below the wet bulb temperature.[2]

It can then be calculated out in two ways.

(*a*) By Mr Glaisher's factors.—By comparison of the result of Daniell's hygrometer and the dry and wet bulb thermometers for a long term of years, Mr Glaisher has deduced an empirical formula, which is thus worked. Take

Glaisher's Factors.

Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.
10°	8·78	33°	3·01	56°	1·94	79°	1·69
11	8·78	34	2·77	57	1·92	80	1·68
12	8·78	35	2·60	58	1·90	81	1·68
13	8·77	36	2·50	59	1·89	82	1·67
14	8·76	37	2·42	60	1·88	83	1·67
15	8·75	38	2·36	61	1·87	84	1·66
16	8·70	39	2·32	62	1·86	85	1·65
17	8·62	40	2·29	63	1·85	86	1·65
18	8·50	41	2·26	64	1·83	87	1·64
19	8·34	42	2·23	65	1·82	88	1·64
20	8·14	43	2·20	66	1·81	89	1·63
21	7·88	44	2·18	67	1·80	90	1·63
22	7·60	45	2·16	68	1·79	91	1·62
23	7·28	46	2·14	69	1·78	92	1·62
24	6·92	47	2·12	70	1·77	93	1·61
25	6·53	48	2·10	71	1·76	94	1·60
26	6·08	49	2·08	72	1·75	95	1·60
27	5·61	50	2·06	73	1·74	96	1·59
28	5·12	51	2·04	74	1·73	97	1·59
29	4·63	52	2·02	75	1·72	98	1·58
30	4·15	53	2·00	76	1·71	99	1·58
31	3·60	54	1·98	77	1·70	100	1·57
32	3·32	55	1·96	78	1·69		

[1] *Hygrometrical Tables*, 6th edition, 1877. A copy is now sent to each station.

[2] Occasionally the wet bulb may read higher than the dry, as in thick fog or during very calm, cold weather. This is rare, but should it be met with, then the temperature of the dry bulb is to be taken and considered to be at saturation (Scott).

the difference of the dry and wet bulb, and multiply it by the factor which stands opposite the *dry-bulb* temperature in the preceding table, deduct the product from the *dry-bulb* temperature; the result is the dew-point. From this formula Glaisher's tables are calculated.

(*b*) *Apjohn's Formula.*—From a most philosophical and exhaustive analysis of the conditions of this complicated problem, Dr Apjohn derived his celebrated formula, which is now in general use. Reduced to its most simple expression, it is thus worked:—A table of the elastic tension of vapour, in inches of mercury at different temperatures, must be used. From this table take out the elastic tension of the temperature of the *wet* thermometer, and call it f'. Let $(t-t')$ be the difference of the two thermometers, and p the observed height of the barometer. Apjohn's formula then enables us to calculate the elastic tension of the dew-point, which we will call f''; and, this being known, by looking in the table we obtain, opposite this elastic tension, the dew-point temperature.

The formula is:

$$f'' = f' - 0{\cdot}01147(t-t')\frac{p-f'}{30}.$$

The fraction $\frac{p-f'}{30}$ differs but little from unity, and may be neglected; the formula then becomes, for the temperature above 32° Fahr.,

$$f'' = f' - \frac{(t-t')}{87}.$$

If below 32° the formula is: $f'' = f' - \frac{(t-t')}{96}$.

The *dew-point* being known, the *weight of a cubic foot of vapour*, and the amount of *elastic tension*, expressed in inches of mercury (if this is desired), are taken from tables; the *relative humidity* is got by calculation, or from tables.

The *relative humidity* is merely a convenient term to express comparative dryness or moisture. Complete saturation being assumed to be 100, any degree of dryness may be expressed as a percentage of this, and is obtained at once by dividing the weight of vapour actually existing by the weight of vapour which would have been present had the air been saturated.

In order to save trouble, all these points, and other matters of interest, such as the weight of a cubic foot of dry air, or of mixed dry and moist air, are given in Mr Glaisher's *Hygrometrical Tables*, which all medical officers are advised to get.

The amount of watery vapour can also be told by a hair hygrometer. A modification of Saussure's hygrometer is still used in France, and also in Russia and Norway. A human hair, freed from fat by digestion in liquor potassæ or ether, is stretched between a fixed point and a small needle, which traverses a scale divided into 100 parts. As the hair shortens or elongates the needle moves and indicates the relative humidity.[1] The scale is graduated by wetting the hair for complete saturation, and by placing it over sulphuric acid of known strength for fifteen degrees of saturation.[2] A very delicate instrument is thus obtained, which indicates even momentary changes in moisture. On comparison with the wet and dry bulb, it has been found to give accordant results for three or four months; it then

[1] Hair shortens when dry and elongates when moist.
[2] The graduation of the scale is explained in *The Arctic Manual*, p. 16.

gradually stretches, and requires to be a little wound up. If compared with the dry and wet bulb, the hair hygrometer seems to be exact enough for experiments in ventilation, for which it is adapted from its rapidity of indication. It has also been recommended by the Vienna congress for use in extreme climates, when the indications of the psychrometer are either uncertain or entirely astray.[1] The horse-hair hygrometer of Wolpert is also much used in Germany.

The amount of watery vapour in the air has a considerable effect on the temperature of a place. Hermann von Schlagintweit[2] has pointed out that the differences between the temperature marked in the sun and shade by two maximum thermometers are chiefly dependent on the amount of humidity. The maxima of insolation (measured by the difference between the sun and shade thermometers) occur in those stations and on those days when humidity is greatest. Thus, at Calcutta, the relative humidity being 80 to 93, the insolation (or difference between the thermometers) is 50° Fahr.; at Bellari, the relative humidity being 60 to 65, the insolation is 8° to 11°. These results are explained by Tyndall's observations, which show that the transparent humidity will scarcely affect the sun's rays striking on the sun thermometer, while it greatly obstructs the radiation of invisible heat from the thermometer; when the air is highly charged with moisture, the sun thermometer is constantly gaining heat from the sun's rays, while it loses little by radiation, or if it does lose by radiation, gains it again from the air.

When watery vapour mixes with dry air, the volume of the latter is augmented; the weight of a cubic foot of dry air at 60° Fahr. is 536·28 grains, and that of a cubic foot of vapour at 60° is 5·77 grains; the conjoint weights would be 542·05 grains at 60°, but, owing to the enlargement of the air, the actual weight of a cubic foot of saturated air at 60° is only 532·84.

SECTION III.

BAROMETER.

A good mercurial barometer is supplied to many army stations; the scale is brass, graduated on the scale to 20ths or half-tenths, and is read to $\frac{2}{1000}$ths by means of a vernier. There is a movable bottom to the cistern, which is worked up and down by a screw, so as to keep the mercury in the cistern at the same level. Correction for capacity is thus avoided.

To fix the Barometer.—Choose a place with a good light, yet protected from direct sunlight and rain; fix the frame sent with the barometer very carefully with a plumb-line, so as to have it exactly perpendicular; then hang the barometer on the hook, and adjust it gently by means of the three screws at the bottom, so that it hangs truly in the centre. Test this by the plumb-line (a 4-oz. weight tied to a string will do), and then unscrew the bottom of the cistern till the ivory point is seen.

Before fixing the barometer the bottom should be unscrewed till the mercury is two or three inches from the top; the barometer should be rather suddenly inclined, so as to let the mercury strike against the top; if there is no air it will do this with a sharp click; if there be air there is no click; in that case screw up the mercury again till the tube is full, turn the barometer upside down, and tap the side forcibly till you see the globule of air

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[1] See Scott's *Instructions*, p. 47.

[2] *Proceedings of the Royal Society*, vol. xiv. p. 111, 1865.

passing up the tube through the mercury into the cistern. Do not be afraid of doing this; there is no danger of any damage to the instrument.

Reading of Barometer.—Read the attached thermometer first; then adjust the cistern, so that the ivory point, known as the fiducial point, perceptible through the glass wall of the cistern, seems just to touch the point of the image in the mercury. Then adjust the vernier, so as to cut off the light from the *top* of the mercury, and thus be an exact tangent to the meniscus. Then read the scale with the help of the vernier.

A little difficulty is sometimes experienced, by those who are not accustomed to such instruments, in understanding the vernier. It will be, probably, comprehended from a little description, read with the instrument before us. On the scale of the barometer itself, it will be seen that the smallest divisions correspond to half-tenths, that is, to $\frac{5}{100}$ths of an inch ($=0{\cdot}05$). The height of the mercury can be read thus far on the scale itself. The vernier is intended to enable us to read the amount of space the top of the mercury is above or below one of these half-tenth lines. It will be observed that the vernier is divided into twenty-five lines; but on adjusting it, so that its lower line corresponds with a line indicating an inch, it will be seen that its twenty-five divisions only equal twenty-four half-tenth divisions on the scale. The result is, that each division on the vernier is $\frac{1}{25}$th less than a half-tenth division on the scale. One $\frac{1}{25}$th of a half-tenth is $\frac{2}{1000}$ths of an inch ($0{\cdot}05 \div 25 = 0{\cdot}002$ inch). This being understood, adjust the vernier so that its *lowest* line accurately corresponds to any line on the scale. It will then be seen that its lowest line but one is a little distance below (in fact, 0·002 inch) the next line on the fixed scale. Raise now the vernier, so that its second line shall correspond to the line on the scale to which it was a little below; and of course the bottom of the vernier must be raised 0·002 inch above the line it first corresponded with. If the next line, the third on the vernier, be made to correspond with the line on the scale just above it, the bottom of the scale must be raised double this (0·004 inch) above the line it was first level with; if the next line on the vernier be made to correspond with a line on the scale, the scale is raised 0·006, and so on. Each division on the vernier equals 0·002 inch, and each five divisions equals $\frac{1}{100}$th, or 0·01 inch.

The barometer is read thus:—The vernier being adjusted to the top of the mercury, read on the *scale* to the half-tenth; then look above, and see what line on the *vernier* corresponds exactly to a line on the scale. Then read the number on the vernier, counting from the bottom; multiply by 0·002, and the result is the number of thousandths of an inch the top of the mercury is above the half-tenth line next below it.[1] Add this number to that already got by direct reading of the fixed scale, and the result is the height of the mercury in inches and decimals of an inch.

Corrections for the Barometer.—The barometer supplied to military stations requires no corrections for capacity. There are two constant corrections for all barometers, viz., capillarity and index error. The first depends on the size of the bore, and whether the mercury has been boiled in the tube or not. Index error is determined by comparison with a standard barometer. The index and capillarity errors are put together. The capillarity error is always additive; the index error may be subtractive or additive, but the two together form a constant quantity, and the certifi-

[1] Instead of multiplying the number on the vernier by 0·002, a little practice will enable the calculation to be made at once. On the vernier will be seen the figures 1, 2, 3, 4, and 5; corresponding to the 5th, 10th, 15th, 20th, and 25th lines, and indicating 0·01, 0·02, 0·03, 0·04, or 0·05 inch. Each line between these numbered lines equals 0·002 inch.

cates furnished by the Kew Observatory, for all barometers verified there, include both corrections above mentioned.

Corrections for Temperature.—The barometer readings are, to facilitate comparison, always reduced to what they would have been were both scale and mercury at 32° F. If the temperature of the mercury be above this, the metal expands, and reads higher than it would do at 32°. The amount of expansion of mercury is 0·0001001 of its bulk for each degree; but the linear expansion of the brass scale must be also considered.

Schumacher's formula is used for the correction, viz.,

h = observed height of barometer in inches.
t = temperature of attached thermometer (Fahr.).
m = expansion of mercury per degree—viz., 0·0001001 of its length at 32
s = linear expansion of scale, viz., 0·00001041; normal temperature being 62°.

$$-h\,\frac{m\,(t-32^\circ)-s\,(t-62^\circ)}{1+m\,(t-32^\circ)}.$$

To facilitate the correction for temperature, tables are given in Mr R. H. Scott's *Instructions in the Use of Meteorological Instruments*, which is distributed to medical officers.

Correction for Altitude above Sea-Level.—As the mercury falls about $\frac{1}{1000}$ (0·001 inch)[1] for every foot of ascent, this amount multiplied by the number of feet must be added to the height, if the place be above sea-level.[2] The temperature of the air has, however, also to be taken into account if great accuracy is required. Tables for correcting for small altitudes are given in Scott's *Instructions.*

When all these corrections have been made, the exact height of the mercury represents the conjoint weights of the oxygen, nitrogen, carbon dioxide, and watery vapour of the atmosphere. It is difficult to separate these several weights, and late observations, which show that the humidity existing at any place is merely local, and that vapour is most unequally diffused through the air, render it quite uncertain what amount of the mercury is supported by the watery vapour. Yet that this has a considerable effect in altering the barometric height, particularly in the tropics, seems certain (Herschel).

The height of the barometer at sea-level differs at different parts of the earth's surface, being less at the equator (29·974) than on either side of 30° N. and S. lat., and lessening again towards the poles, especially towards the south, from 63° to 74° S. lat., where the depression is upwards of an inch. It also differs in different places according to their geographical position. Like the thermometer, it is subjected to diurnal and annual periodic changes and to non-periodic undulations.

In the tropics the diurnal changes are very steady: there are two maxima and two minima; the first maximum is about 9 A.M.; the first minimum about 3 to 4 P.M.; the second maximum at 10 P.M.; the second minimum at 4 A.M. These changes are, perhaps, chiefly dependent on the watery vapour (Herschel). In this country the diurnal range is less, but occurs at about the same hours. The undulations depend on the constantly shifting currents of air, rendering the total amount of air over a place heavier or lighter. The wind tends to pass towards the locality of least barometric

[1] The exact amount is a little below this, but varies with altitude; at sea-level the amount is 0·000886 for every foot of ascent.

[2] For the British Isles, the mean sea-level at Liverpool has been selected by the Ordnance Survey as their datum.

pressure. In this country the barometer falls with the south-west winds, rises with the north and east; the former are moist and warm, the latter dry and cold winds.

Isobarometric lines are lines connecting places with the same barometric pressure.

Measurement of Heights.—The barometer falls when heights are ascended, as a certain weight of air is left below it. The diminution is not uniform, for the higher the ascent the less weighty the air, and a greater and greater height must be ascended to depress the barometer one inch. This is illustrated by the following table:[1]—

To lower from	31	inches to	30 =	857	feet must be	ascended.
„	30	„	29 =	886	„	„
„	29	„	28 =	918	„	„
„	28	„	27 =	951	„	„
„	27	„	26 =	986	„	„
„	26	„	25 =	1025	„	„
„	25	„	24 =	1068	„	„
„	24	„	23 =	1113	„	„
„	23	„	22 =	1161	„	„
„	22	„	21 =	1216	„	„
„	21	„	20 =	1276	„	„
„	20	„	19 =	1341	„	„
„	19	„	18 =	1413	„	„

The measurements of heights in this way is of great use to medical officers; aneroid barometers can be used, and are very delicate instruments. The new pocket aneroids will measure up to 12,000 or 14,000 feet.

A great number of methods are in use for calculating heights. It can be done readily by logarithms, but then a medical officer may not possess a table of logarithms.

The simplest rule of all is one derived from Laplace's formula. Mr Ellis[2] has stated this formula as follows:—Multiply the difference of the barometric readings by 52,400, and divide by the sum of the barometric readings. If the result be 1000, 2000, 3000, 4000, or 5000, add 0, 0, 2, 6, 14, respectively. Subtract $2\frac{1}{3}$ times the difference of the temperatures of the mercury. Multiply the remainder by a number obtained by adding 836 to the sum of the temperatures of the air and dividing by 900. A correction must also be made for latitude, which can be done by Table III. p. 412.

Tables such as those given by Delcros and Oltmanns are very convenient for estimating heights by the barometer. A table less long than these, but based on the same principle, has been given by Negretti and Zambra in their useful work,[3] and is copied here.

A good mercurial barometer, with an attached thermometer, or an aneroid compensated for temperature, and a thermometer to ascertain the temperature of the air, are required. Two barometers and two thermometers, which can be observed at the same moment at the upper and lower stations, are desirable.

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[1] The height can be readily taken from this table, by calculating the number of feet which must have been ascended to cause the observed fall, and then making a correction for temperature, by multiplying the number obtained from the table, which may be called A, by the formula (t is the temperature of the lower, and t' of the upper station)—

$$\left(1 + \frac{t+t'-64}{900}\right) \times A.$$

[2] *Proceedings of the Royal Society*, 1865, No. 75, p. 283.

[3] *A Treatise on Meteorological Instruments*, by Negretti and Zambra, 1864.

Supposing, however, there is but one barometer, take the height at the lower station, and correct for temperature to 32°. Take the temperature of the air. Ascend as rapidly as possible to the upper station, and take the height of the barometer (correcting it to 32°) and the temperature of the air; then use the accompanying tables, taken from Negretti and Zambra's work. If the height is less than 3000 feet, Tables II., III., and IV. need not be used.

"Table I. is calculated from the formula, height in feet = 60,200 (log. 29·922—log. B) + 925; where 29·922 is the mean atmospheric pressure at 32° Fahr., and at the mean sea-level in latitude 45°; and B is any other barometric pressure; the 925 being added to avoid *minus* signs in the table.

TABLE I.—*Approximate Height due to Barometric Pressure.*

Inches of Barometer.	Feet.	Inches of Barometer.	Feet.	Inches of Barometer.	Feet.
31·0	0	27·3	3,323	23·6	7,131
30·9	84	·2	3,419	·5	7,242
·8	169	·1	3,515	·4	7,353
·7	254	27·0	3,612	·3	7,465
·6	339	26·9	3,709	·2	7,577
·5	425	·8	3,806	·1	7,690
·4	511	·7	3,904	23·0	7,803
·3	597	·6	4,002	22·9	7,917
·2	683	·5	4,100	·8	8,032
·1	770	·4	4,199	·7	8,147
30·0	857	·3	4,298	·6	8,262
29·9	944	·2	4,398	·5	8,378
·8	1,032	·1	4,498	·4	8,495
·7	1,120	26·0	4,588	·3	8,612
·6	1,208	25·9	4,699	·2	8,729
·5	1,296	·8	4,800	·1	8,847
·4	1,385	·7	4,902	22·0	8,966
·3	1,474	·6	5,004	21·9	9,085
·2	1,563	·5	5,106	·8	9,205
·1	1,653	·4	5,209	·7	9,325
29·0	1,743	·3	5,312	·6	9,446
28·9	1,833	·2	5,415	·5	9,567
·8	1,924	·1	5,519	·4	9,689
·7	2,015	25·0	5,623	·3	9,811
·6	2,106	24·9	5,728	·2	9,934
·5	2,198	·8	5,833	·1	10,058
·4	2,290	·7	5,939	21·0	10,182
·3	2,382	·6	6,045	20·9	10,307
·2	2,475	·5	6,152	·8	10,432
·1	2,568	·4	6,259	·7	10,558
28·0	2,661	·3	6,366	·6	10,684
27·9	2,754	·2	6,474	·5	10,812
·8	2,848	·1	6,582	·4	10,940
·7	2,942	24·0	6,691	·3	11,069
·6	3,037	23·9	6,800	·2	11,198
·5	3,132	·8	6,910	·1	11,328
27·4	3,227	23·7	7,020	20·0	11,458

"Table II. contains the correction necessary for the mean temperature of the stratum of air between the stations of observation; and is computed from Regnault's coefficient for the expansion of air, which is 0·002036 of its volume at 32° for each degree above that temperature.

TABLE II.—*Correction due to Mean Temperature of the Air, the Temperature of the Upper and Lower Stations being added and divided by 2.*

Mean Temp.	Factor.	Mean Temp.	Factor.	Mean Temp.	Factor.
10°	0·955	35°	1·006	60°	1·057
11	·957	36	1·008	61	1·059
12	·959	37	1·010	62	1·061
13	·961	38	1·012	63	1·063
14	·963	39	1·014	64	1·065
15	·965	40	1·016	65	1·067
16	·967	41	1·018	66	1·069
17	·969	42	1·020	67	1·071
18	·971	43	1·022	68	1·073
19	·974	44	1·024	69	1·075
20	·976	45	1·026	70	1·077
21	·978	46	1·029	71	1·079
22	·980	47	1·031	72	1·081
23	·982	48	1·033	73	1·083
24	·984	49	1·035	74	1·086
25	·986	50	1·037	75	1·088
26	·988	51	1·039	76	1·090
27	·990	52	1·041	77	1·092
28	·992	53	1·043	78	1·094
29	·994	54	1·045	79	1·096
30	·996	55	1·047	80	1·098
31	0·998	56	1·049	81	1·100
32	1·000	57	1·051	82	1·102
33	1·002	58	1·053	83	1·104
34	1·004	59	1·055	84	1·106

"Table III. is the correction due to the difference of gravitation in any other latitude, and is found from the formula, $x = 1 + 0{\cdot}00265 \cos 2 \text{ lat.}$

TABLE III.—*Correction due to Difference of Gravitation in Different Latitudes.*

Latitude.	Factor.	Latitude.	Factor.	Latitude.	Factor.
80°	0·99751	50°	0·99954	20°	1·00203
75	0·99770	45	1·00000	15	1·00230
70	0·99797	40	1·00046	10	1·00249
65	0·99830	35	1·00090	5	1·00261
60	0·99868	30	1·00132	0	1·00265
55	0·99910	25	1·00170		

"Table IV. is to correct for the diminution of gravity in ascending from the sea-level.

"To use these tables: The barometer readings at the upper and lower stations having been corrected and reduced to temperature 32° Fahr., take out from Table I. the numbers opposite the corrected readings of the two barometers, and subtract the lower from the upper. Multiply this difference successively by the factors found in Tables II. and III. The factor from Table III. may be neglected unless great precision is desired. Finally, add the correction taken from Table IV." (Negretti and Zambra.)

In the table the barometer is only read to 10ths, but it should be read to

100ths (0·01) and 1000ths (0·001), and the number of feet corresponding to these amounts calculated from the table, which is easy enough.

TABLE IV.

Height in Thousand Feet.	Correction Additive.	Height in Thousand Feet.	Correction Additive.
1	3	9	26
2	5	10	30
3	8	11	33
4	11	12	37
5	14	13	41
6	17	14	44
7	20	15	48
8	23		

Example.—At two stations the barometer read respectively 29·9 and 21·2, the temperatures of the air being 60° and 40°.

Barometer at upper station,	21·2, Table I.,	9,934
,, lower ,,	29·9, ,,	944
Approximate height,		8,990
Mean temperature 50°, Table II., Factor,		1·037
Height corrected for temperature,		9,323
Latitude (say) 30°, Table III., Factor,		1·00132
Height corrected for latitude,		9,353
Correction from Table IV.,		26
Height corrected for altitude,		9,378
Height of lower station above sea-level (say),		150
Final corrected height of upper station above sea-level,		9,528

A very simple rule for approximative determinations has been given by Mr R. Strachan.[1] Read the aneroid to the nearest hundredth of an inch: subtract the upper reading from the lower, leaving out or neglecting the decimal point: multiply the difference by 9: the product is the elevation in feet.

Example.

	Inches.
Lower station,	30·25
Upper ,,	29·02
	123
	9
Elevation,	1107 feet.

If the barometer at the upper station is below 26 inches, or the temperature above 70°, the multiplier should be 10.

Weight of the Air.—The barometer expresses the weight of the air in inches of mercury. The actual weight can be determined if the reading of the barometer, temperature, and humidity are all known.

The weight of a cubic foot of dry air, at 32° Fahr. and normal pressure, is 566·85 grains. For any other temperature the weight can be calculated. Multiply the coefficient of the expansion of air (viz., 0·0020361 for 1° Fahr.) by the number of degrees above 32, the sum added to unity will give the

[1] *Pocket Altitude Tables*, by G. J. Symons, F.R.S., 3rd ed., 1880, p. 5.

volume of a cubic foot of dry air at that temperature. Divide 566·85 by the number so obtained. The result is the weight of the dry air at the given temperature.

SECTION IV.

RAIN.

Rain is estimated in inches; that is, the fall of an inch of rain implies that on any given area, say a square yard of surface, rain has fallen equal to one inch in depth. The amount of rain is determined by a rain-gauge. Two gauges are supplied for military stations; one to be placed on the ground, one 20 feet above it; in all parts of the world the latter indicates less rain than the lower placed gauge; this is due to wind.[1]

Several kinds of gauges are in use. The one used by the Army Medical Department is a cylindrical tin box with a rim or groove at the top; a circular top with a funnel inside fits on to this groove, which, when filled with water, forms a water valve. The opening above is circular (the circle being made very carefully, and a rim being carried round it to prevent the rain-drops from being whirled by wind out of the mouth), and descends funnel-shaped, the small end of the funnel being turned up to prevent evaporation. But leaves, dust, or insects sometimes choke this tube, so that it is now generally straightened, the loss by evaporation being insignificant compared with that caused by obstruction. The best size for the open top, or, in other words, the area of the receiving surface, is from 50 to 100 square inches. The lower part of the box is sunk in the ground nearly to the groove; the upper part is then put on, and a glass vessel is placed below the funnel to receive the water.[2] At stated times (usually at 9 A.M. daily) the top is taken off, the glass vessel taken out, and the water measured in a glass vessel, graduated to hundredths of an inch, which is sent with the gauge.[3]

If snow falls instead of rain, it must be melted and the resulting water measured. This may be easily done by adding a measured quantity of warm water, and then subtracting the amount from the total bulk of water.

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[1] See *British Rainfall* (G. J. Symons, F.R.S.), 1872, p. 33, and 1881, p. 41.

[2] A glass vessel should not be used in winter, for fear of breakage in frost.

[3] If this glass is broken it can be replaced by the following rule, or a rain-gauge can be made. It need not be round, though this is now thought the best form, but may be a square box of metal or wood, and may be of any size between 3 and 24 inches in diameter, but 5 to 8 is the most convenient range.

Determine the area, in square inches, of the receiving surface, or top of the gauge, by careful measurement. This area, if covered with water to the height of one inch, would give us a corresponding amount of cubic inches. This number of cubic inches is the measure for that gauge of one inch, because when the rain equals that quantity it shows that one inch of rain has fallen over the whole surface.

Let us say the area of the receiving surface is 100 square inches. Take 100 cubic inches of water and put it into a glass, put a mark at the height of the fluid, and divide the glass below it into 100 equal parts. If the rainfall comes up to the mark, one inch of rain has fallen on each square inch of surface; if it only comes up to a mark below, some amount less than an inch (which is so expressed in $\frac{1}{10}$ths and $\frac{1}{100}$ths) has fallen.

To get the requisite number of cubic inches of water we can weigh or measure. A cubic inch of water at 62° weighs 252·458 grains, consequently 100 cubic inches will be $(252·458 \times 100) = 25245·8$ grains, or 57·7 ounces avoir. But an easier way still is to measure the water:—an ounce by measure is equal to 1·728 cubic inches, therefore divide 100 by 1·728, and we obtain the number of ounces avoir. which corresponds to 100 cubic inches. It is always best, however, to use a gauge made by a regular maker, if possible, as inaccurate records are worse than none.

Usually a one-inch measure is so large a glass that half an inch is considered more convenient.

From a table of the weight of vapour, it will be seen that the amount of vapour which can be rendered insensible increases with the temperature, but not regularly; more, comparatively, is taken up by the high temperatures; thus, at 40°, 2·86 grains are supported in a cubic foot of air; at 50°, 4·10 grains, or 1·24 grains more; at 60°, 5·77 grains, or 1·67 grains more than at 50°. Therefore, if two currents of air of unequal temperatures, but equally saturated with moisture, meet in equal volume, the temperature will be the mean of the two, but the amount of vapour which will be kept invisible is less than the mean, and some vapour therefore necessarily falls as fog or rain. Thus one saturated current being at 40°, and the other at 60°, the resultant temperature will be 50°, but the amount of invisible vapour will not be the mean, viz., 4·315, but 4·1; an amount equal to 0·215 will therefore be deposited.

Rain is therefore owing to the cooling of a saturated air, and rain is heaviest under the following conditions,—when, the temperature being high, and the amount of vapour large, the hot and moist air soon encounters a cold air. These conditions are chiefly met with in the tropics, when the hot air, saturated with vapour, impinges on a chain of lofty hills over which the air is cold. The fall may be 130 to 160 inches, as on the Malabar coast of India, or 180 to 220 in Southern Burmah, or 600 at Cherrapunjī, in the Khasyah Hills. Even in our own country the hot air from the Gulf Stream impinging on the Cumberland Hills causes, in some districts, a fall of 80, 100, 200, and even more inches in the year.

The average of the kingdom is about 30 inches, which is exactly that of Netley (30·12), on an average of 23 years, 1864–86.

The rainfall in different places is remarkably irregular from year to year; thus at Bombay, the mean being 76, in 1822 no less than 112 inches, while in 1824 only 34, inches fell.

The amount of rain at the different foreign stations is given under the respective headings.

SECTION V.

EVAPORATION.

The amount of evaporation from a given moist surface is a problem of great interest, but it is not easy to determine it experimentally, and no instrument is issued by the Army Medical Department. A shallow vessel of known area, protected round the rim by wire to prevent birds from drinking, is filled with a known quantity of water, and then, weekly or monthly, the diminution of the water is determined, the amount added by rain as shown by the rain-gauge being of course allowed for.

Water has been placed under a cover, which may protect it from rain and dew, and yet permit evaporation, and the loss weighed daily; but it is impossible to insure that the evaporation shall be equal to that under the free heavens.

A third plan is calculating the rate of evaporation from the depression of the wet-bulb thermometer, by deducting the elastic force of vapour at the dew-point temperature from the elastic force at the air temperature, and taking the difference as expressing the evaporation. This difference expresses the force of escape of vapour from the moist surface.

Instruments termed *Atmometers* have been used for this purpose; the first was invented by Leslie. A ball of porous earthenware was fixed to a glass tube, with divisions, each corresponding to an amount of water which

would cover the surface of the ball with a film equal to the thickness of $\frac{1}{1000}$th part of an inch. The evaporation from the surface of the ball was then read off. Dr Babington has also invented an ingenious *Atmidometer*.[1]

The amount of evaporation is influenced by temperature, wind, humidity of the air, rarefaction of the air, degree of exposure or shading, and by the nature of the moist surface; it is greater from moist soil than from water.

The amount of vapour annually rising from each square inch of water surface in this country has been estimated at from 20 to 24 inches; in the tropical seas it has been estimated at from 80 to 130, or even more inches. In the Indian Ocean it has been estimated at as much as an inch in twenty-four hours, or 365 in the year, an almost incredible amount. No doubt, however, the quantity is very great.

It requires an effort of imagination to realise the immense distillation which goes on from the tropical seas. Take merely 60 inches as the annual distillation, and reckon this in feet instead of inches, and then proceed to calculate the weight of the water rising annually from such a small space as the Bay of Bengal. The amount is almost incredible.

This distillation of water serves many great purposes. Mixing with the air it is a vast motive power, for its specific gravity is very low (0·6230, air being 1), and it causes an enlargement of the volume of air; the moist air is therefore much lighter, and ascends with great rapidity; the distillation also causes an immense transference of heat from the tropics, where the evaporation renders latent a great amount of heat, to the extra-tropical region where this vapour falls as rain, and consequently parts with its latent heat. The evaporation also has been supposed to be a great cause of the ocean currents (Maury), which play so important a part in the distribution of winds, moisture, and warmth.

SECTION VI.

WIND.

Direction.—For determining the direction of the wind a vane is necessary. It should be placed in such a position as to be able to feel the influence of the wind on all sides, and not be subjected to eddies by the vicinity of buildings, trees, or hills. The points must be fixed by the compass,[2] the magnetic declination being taken into account; the declination of the place must be obtained from the nearest Observatory; in this country it is now a little under 18° (or two points) to the westward of true north.[3] The direction of the wind is registered twice daily in the army returns, but any unusual shifting should receive a special note. The course of the wind is not always parallel with the earth; it sometimes blows slightly downwards; contrivances have been employed to measure this, but the matter does not seem important.

To ascertain the mean direction of the wind: give a numerical value to each observation, and then analyse them. Thus, suppose we read to 16 points and give a numerical value of 6 to each observation: if the wind were, say, due N., then we should have 6 N.; if N.W., we should have 3 N. and 3 W.; if N.N.W., we should have 4 N. and 2 W. Suppose now we have the

[1] See Negretti and Zambra's *Treatise*, p. 141, for details.
[2] Or, better still, by the pole star.
[3] Thus N. magnetic will be N.N.W. true, S. magnetic S.S.E. true, and so on.

following observations:—N., N.W., N.N.W., S.E., E.S.E., S.W., W.S.W., S., S.W.; giving each a numerical value of 6 we should have—

		N.	S.	E.	W.			N.	S.	E.	W.
N.	=	6	...	...	...	E.S.E.	=	...	2	4	...
N.W.	=	3	...	....	3	S.W.	=	...	3	...	3
W.	=	...	...	...	6	W.S.W.	=	...	2	...	4
N.N.W.	=	4	...	...	2	S.	=	...	6	...	...
S.E.	=	...	3	3	...	S.W.	=	...	3	...	3

Then setting off the opposite directions against each other we should have—

S. 19	W. 21
N. 13	E. 7
Net, S. 6	Net, W. 14

This would give us an angle of about 66°, or a mean direction of nearly W.S.W.

Velocity.—A small Robinson's anemometer is now supplied to each station; it is read every twenty-four hours, and marks the horizontal movement in the preceding twenty-four hours.

This anemometer consists of four small cups,[1] fixed on horizontal axes of such a length (1·12 feet between two cups), that the centre of a cup, in one revolution, passes over $\frac{1}{1500}$th of a mile, the circumference being 3·52 feet. These cups revolve with about a third of the wind's velocity; 500 revolutions of the cups are therefore supposed to indicate one mile, and by an arrangement of wheels the number of miles traversed by the wind can be approximately ascertained.

Osler's anemometer is a large and very beautiful instrument. It registers simultaneously, on a piece of paper fitted on a drum which is turned by clock-work, direction, velocity, and pressure.

Casella's self-registering instruments register velocity and direction in a very ingenious way.

Other anemometers, Lind's, Whewell's, &c., need not be described.

The average velocity of wind in this country near the surface of the earth is from 6 to 8 miles per hour; its range is from something over zero to 60 or even 70 miles per hour, but this last is very rare; it is seldom more, even in heavy winds, than 35 to 45 miles per hour. In the hurricanes of the Indian and China seas it is said to reach 100 to 110 miles per hour.

Force.—The force of the wind is reckoned as equal to so many pounds or parts of a pound on a square foot of surface. Osler's anemometer, as just stated, registers the force, as well as the velocity and direction, but Robinson's (used in the army) marks only the velocity; the force must then be calculated. The rule for the calculation of the force from the velocity is as follows:—

Ascertain the mean velocity per hour by observing the velocity for a minute and multiplying by 60; then square the hourly velocity and multiply by 0·005. The result is the pressure in pounds or parts of a pound per square foot.

The formula is, if V = velocity per hour,

$$V^2 \times \cdot 005 = P.$$

If the force be given, the velocity may be found:

$$\sqrt{200\, P} = V.$$

[1] The current of air is opposed one-fourth more by a concave surface than by a convex one the same size.

When no anemometer is in use, the Beaufort scale may be employed, 0 = calm, about 3 miles an hour,—and 12 = hurricane, 90 miles and over.

SECTION VII.

CLOUDS (PLATE IX.).

The nomenclature proposed by Howard[1] is now almost universally adopted.

There are three principal forms and four modifications.

Principal Forms.

Cirrus.—Thin filaments, which by association form a brush, or woolly hair, or a slender net-work. They are very high in the atmosphere, probably more than 10 miles, but the exact height is unknown. It has even been questioned whether they are composed of water; if so, it must be frozen. In this climate they come from the north-west.

Cumulus.—Hemispherical or conical heaps like mountains rising from a horizontal base; cumuli are often compared to balls of cotton.

Stratus.—A widely extended, continuous horizontal sheet, often forming at sunset.

Modifications.

Cirro-cumulus.—Small rounded, well-defined masses, in close, horizontal arrangement; when the sky is covered with such clouds it is said to be fleecy.

Cirro-stratus.—Horizontal strata or masses, more compact than the cirri; at the zenith they seem composed of a number of thin clouds; at the horizon they look like a long narrow band.

Cumulo-stratus.—Stratus blended with cumulus.

Cumulo-cirro-stratus, *Nimbus*, or *Rain-cloud.*—A horizontal sheet above which the cirrus spreads, while the cumulus enters it laterally or from below.

Of the above forms Nos. 1, 2, and 3 of the plate (copied by permission from Mr Scott's *Instructions*) are "upper" clouds; the others are "lower" clouds. To those described is added the form shown in No. 5, viz., *Roll-cumulus*, which consists of portions of cumulus rolled into a cylindrical shape, and either separate or packed together, as shown in the plate. Alongside the names in the plates are contractions, which ought to be used in description.

Estimation of Amount of Cloud.—This is done by a system of numbers: 0 expresses a cloudless sky, 10 a perfectly clouded sky, the intermediate numbers various degrees of cloudiness. To get these numbers, look midway between the horizon and zenith, and then turn slowly round, and judge as well as can be done of the relative amount of clear and clouded sky. This is to be entered without reference to the thickness of the cloud.

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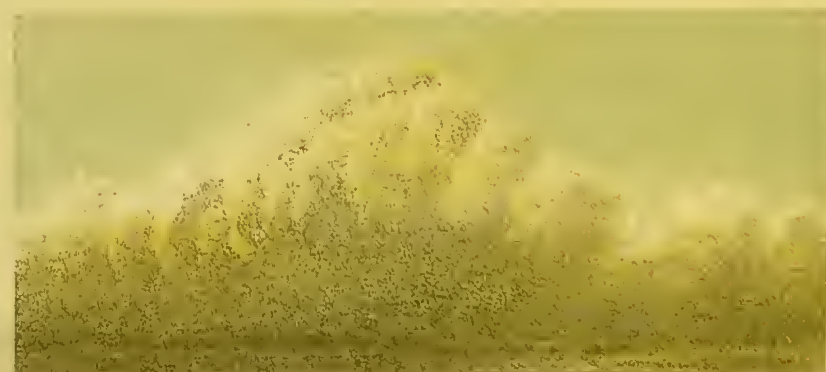
[1] *Climate of London.*

FORMS OF VARIOUS CLOUDS

Fig 1. Cirrus (Cir.)

Fig 5. Roll Cumulus (R.Cu.)

Small Cumulus



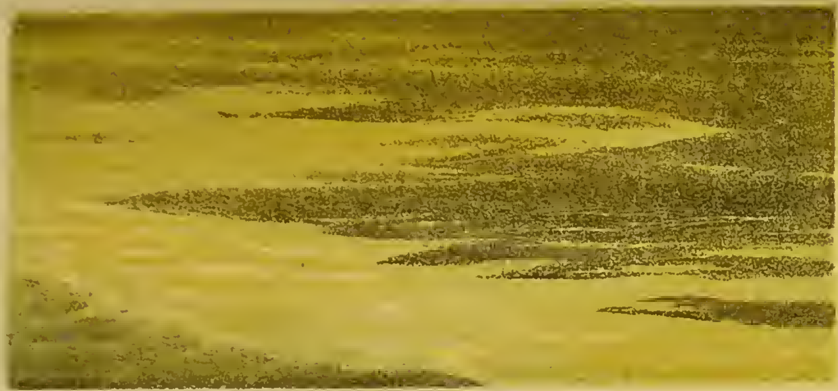


Fig 3 Cirro stratus (*Cir. s.*)

Fig 7. Cumulo-stratus (*Cum. s.*)

Fig 4 Stratus (*Str.*)
a Detached Strata

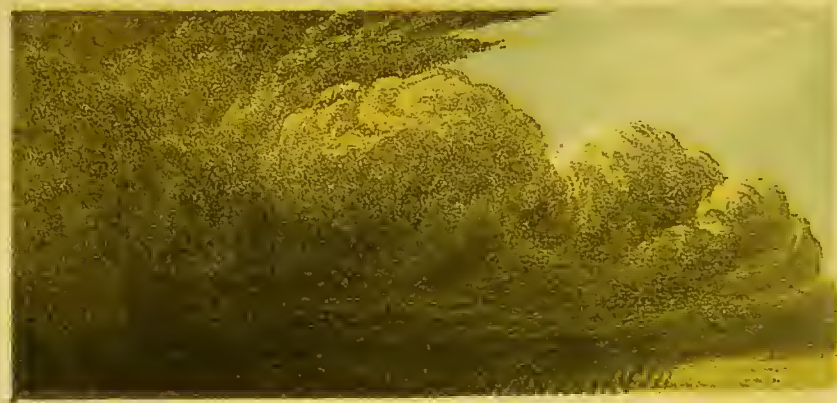


Fig 8 Nimbus (*Nim.*)

Vincent Brooks Day & Son lith

SECTION VIII.

OZONE.[1]

Papers saturated with a composition of iodide of potassium and starch, and exposed to the air, are supposed to indicate the amount of ozone present in the atmosphere. Schönbein, the discoverer of ozone, originally prepared such papers, and gave a scale by which the depth of blue tint was estimated. Subsequently similar but more sensitive papers were prepared by Dr Moffat, and Mr Lowe afterwards improved on Moffat's papers, and also prepared some ozone powders.

The papers are exposed for a definite time to the air, if possible with the exclusion of light, and the alteration of colour is compared with a scale.

Schönbein's proportions are—1 part of *pure* iodide of potassium, 10 parts starch, and 200 parts of water. Lowe's proportion is 1 part of iodide to 5 of starch; Moffat's proportion is 1 to $2\frac{1}{2}$. The starch should be dissolved in cold water, and filtered so that a clear solution is obtained; the iodide is dissolved in another portion of water, and is gradually added. Both must be perfectly pure; the best arrowroot should be used for starch.

The paper, prepared by being cut into slips (so as to dry quicker and to avoid loss of the powder in cutting) and soaked in distilled water, is placed in the mixed iodide and starch for four or five hours, then removed with a pair of pincers, and slowly dried in a cool dark place, in a horizontal position. The last point is important, as otherwise a large amount of the iodide drains down to one end of the paper, and it is not equally diffused. The papers when used should hang loose in a place protected from the sun and rain: a box is unnecessary; they should not be touched with the fingers more than can be helped when they are adjusted.

When Schönbein's papers are used they are moistened with water after exposure, but before the tint is taken. Moffat's papers are prepared somewhat similarly to Schönbein's, but do not require moistening with water.

The estimation of ozone is still in a very unsatisfactory state, and this arises from two circumstances.

1. The fact that other substances besides ozone act on the iodide of potassium, especially nitrous acid, which is formed in some quantity during electrical storms. Cloez has shown that air taken about one metre above the ground often contains nitrous acid in sufficient quantity to redden litmus. Starch and iodide paper is coloured when air contains 0·00005 of its volume of nitrous acid.

2. The fact that the papers can scarcely be put under the same conditions from day to day; light, wind, humidity, and temperature (by expelling the free iodine) all affect the reaction.

Chemical objections have also been made.[2] Supposing that iodine is set free by ozone, a portion of it is at once changed by additional ozone into iodozone, which is extremely volatile at ordinary temperatures, and is also changed by contact with water into free iodine and iodic acid. Hence a portion of the iodine originally set free never acts on the starch, being either volatilised or oxidised. Again, the iodine and caustic potash set free by the ozone combine in part again, and form iodate and iodide of potassium ($\frac{1}{6}$th of the former and $\frac{5}{6}$ths of the latter), and in this way the blue colour

[1] For a full account of the tests of ozone, see Dr Fox's work on *Ozone and Antozone*, 1873, already referred to. After discussing all the tests, he gives the preference to the iodine plan. He has not found Schönbein's thallium method satisfactory.

[2] *Beiträge zur Ozonometrie*, von Dr v. Maach; *Archiv für Wiss. Heilk.*, Band ii. p. 29.

of iodide of starch first produced may be removed. The ozone may possibly, and probably, act on and oxidise the starch itself, and hence another error.

The conclusion arrived at by the Vienna congress was the following:—"The existing methods of determining the amount of ozone in the atmosphere are insufficient, and the congress therefore recommends investigations for the discovery of better methods."

SECTION IX.

ELECTRICITY.

The instruments used by meteorologists are simple electroscopes, with two gold-leaf pieces which diverge when excited, or dry galvanic piles acting on gold-leaf plates or an index attached to a Leyden jar (Thomson's Electrometer). For further details, see Scott's *Instructions, op. cit.*

SECTION X.

THERMOMETER STAND.

A stand is issued by the War Office, and provided at every station where observations are recorded. Or it would be very easy to make a stand with two or three strata of boards, placed about 6 inches apart, so as to form a kind of sloping roof over the thermometers, which are suspended on a vertical board.

The dry and wet bulb thermometers are placed in the centre; the maximum on the right side, and the minimum on the left. The wood should be cut away behind the bulbs of the maximum and minimum thermometers, so as to expose them freely to the air. The bulbs of the dry and wet bulbs should also fall below the board. These stands are made to rotate on the pole so as to turn the roof always to the sun.

A much better stand is Stevenson's screen, a square or oblong box, with double louvred sides and open below. This is raised upon legs four feet from the ground, placed upon grass.[1]

SECTION XI.

WEATHER.

In registering the kind of weather, it is well to adhere to the Beaufort notation and symbols, which are carefully explained in Scott's *Instructions*. Columns are given in the return to be filled up in this way.

SECTION XII.

DISEASES AND VARIATIONS IN THE METEOROLOGICAL ELEMENTS.

The variation in the prevalence of different diseases at a particular place, in connection with the simultaneous variation of meteorological elements, is

[1] Scott's *Instructions*, fig. 10, p. 41.

an old inquiry which has at present led to few results. The reason of this is that the meteorological elements are only a few out of a great many causes affecting the prevalence and severity of diseases. Consequently, in order to estimate the real value of changes of temperature, pressure, humidity, ozone, &c., the other causes of disease, or of variations in prevalence or intensity, must be recognised and eliminated from the inquiry. The best of the modern observations are those by Guy, Ransome, Vernon, Moffat, Tripe, Scoresby-Jackson, Ballard, Mitchell, and Buchan. Observations have also been made by Fodor and others in the continent of Europe, and by various observers in America and elsewhere. But they must be much more extended and numerous before anything practical can be drawn from them.

CHAPTER XVII.

DISINFECTION AND DEODORISATION.

The term *disinfectant*,[1] which has now come into popular use, has unfortunately been employed in several senses. By some it is applied to every agent which can remove impurity from the air;[2] by others to any substance which, besides acting as an air purifier, can also modify chemical action, or restrain putrefaction in any substance, the effluvia from which may contaminate the air; while, by a third party, it is used only to designate the substances which can prevent infectious diseases from spreading, by destroying their specific poisons. This last sense is the most correct, and it is that which is solely used here. The term *disinfectant* might also be applied to substances destroying *entozoa* or *ectozoa*, or *epiphytes* or *entophytes*, but there is a disadvantage in giving it so extended a meaning. The mode in which the poisons are destroyed, whether it be by oxidation, deoxidation, or arrest of growth, is a matter of indifference, provided the destruction of the poison is accomplished. The general term *air purifier* is given in this work to those agents which in any way cleanse the air, and which therefore include disinfectants; and the term *sewage deodorants* to those substances which are used to prevent putrefaction in excreta or in waste animal or vegetable matters, or to remove the products of putrefaction. In a great many instances the substances which are recommended as *disinfectants* are little more than *deodorants*, and ought properly to be spoken of as such.

The chief human diseases which are supposed to spread by means of special agencies (conveniently designated under the name of "contagia")[3] are — the exanthemata; typhus exanthematicus; enteric fever; relapsing fever; yellow fever; paroxysmal and the allied remittent fevers; dengue; cholera; bubo-plague; influenza; hooping-cough; diphtheria; erysipelas; dysentery (in some cases); puerperal fever; syphilis; gonorrhœa; glanders; farcy; malignant pustule; and perhaps phthisis. There are some few others more uncommon than the above.

It has long been a belief that the spread of the infectious diseases might be prevented by destroying the agencies in some way, and various fumigations, fires, and similar plans have been employed for centuries during great epidemics.

In order to apply *disinfection* in the modern sense of the term, we ought to know—1*st*, the nature of these contagious agencies; 2*nd*, the media through which they spread; and, 3*rd*, the effect produced upon them by the chemical methods which are supposed to destroy or modify them.

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[1] The best resumé up to date on the subject of Disinfectants is Vallin's *Traité des Désinfectants*, Paris, 1883.

[2] Tardieu, for example, *Dict. d'Hyg.*, art. "Désinfection," and many other authors.

[3] It will be seen that the old distinctions between *infectious* and *contagious* diseases, and between *miasmata* and *contagia*, are not adhered to. They were at no time thoroughly definite, and are now better abandoned.

1. *The Nature of the Contagia.*[1]

This point is at present the object of eager inquiry. In the case of one or two of the above diseases, the question has been narrowed to a small compass. In variolous and vaccine discharge, and in glanders, the poison certainly exists in the form of solid particles, which can be seen by high powers as glistening points of extreme minuteness.[2] In cattle plague blood serum there are also excessively small particles discovered by Beale, which are probably the poison. The size of the particles supposed to be contagia is minute; some of them are not more than $\frac{1}{50,000}$ of an inch, and Beale believes that there may be smaller still to be discovered with higher powers. Chauveau has washed the vaccine solid particles in water; the water did not become capable of giving the disease; the washed particles retained their power. The epidermic scales of scarlet fever and the pellicle of the diphtheritic membrane certainly contain the respective poisons, and after exposure to the air for weeks, and consequent drying, still retain their potency. It is more likely that solid matters should thus remain unchanged than liquids, but it has not yet been proved that this is so, and at present the exact physical condition of the contagia of the other infectious diseases remains doubtful.

The extraordinary power of increase, and capability of producing their like, possessed by some of the contagia when placed under special fostering circumstances, as in the bodies of susceptible animals, lead to the belief that they are endowed with an independent life. The old doctrines that they are simply either poisonous gases or animal substances in a state of chemical change, and capable of communicating this change, or that, like the so-called ferments (ptyalin, pancreatin, diastase, emulsin), they split up certain bodies they meet, are not now in favour.

The retention of the power of contagion for some time, and its final loss, the destruction of the power by antiseptics which do not affect the action of such bodies as ptyalin or diastase, and the peculiar incubative period, which is most easily explained by supposing a gradual development of the active agent in the body, are more in accordance with the hypothesis of independent life and power of growth.

The independent living nature of the contagia is a belief which has long been held in various forms. At the present time there are three views, each of which has some arguments in its favour.

(1) The particles are supposed to be of animal origin, born in and only growing in the body; they are, in fact, minute portions of bioplasm (to use Dr Beale's phrase) or protoplasm.[3]

This is the old doctrine of "fomites" expressed in a scientific form, and supported by a fact which was not known until recently. This is that the independent life ascribed to these particles of bioplasm is no assumption, since we are now aware that many of the small animal cells or bioplastic molecules are virtually independent organisms, having movements, and apparently searching for food, growing, and dying.

This view explains singularly well the fact of the frequent want of power

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[1] See Report on Hygiene for 1872 (*Army Medical Department Report*, vol. xiii.).

[2] The observations of Chauveau, Beale, and Burdon-Sanderson, and still more recently of Braidwood and Vacher, prove this very important point by what seems indisputable evidence. It does not follow that all small bodies are in such fluids the *contagia*, but the experiments prove that some of them must be. In many kinds of blood there are numerous small particles, derived, according to Riess, from retrograde metamorphosis of white blood cells, and these have no contagious property.

[3] This view has been advocated with great force by Beale (*Disease Germs*, 2nd edition) and Morris (*The Germ Theory of Disease*, 2nd edition).

of the contagia of one animal to affect another family; as, for example, the non-transference of many human diseases to brutes, and the reverse. It also partly explains the non-recurrence of the disease in the same animal by supposing an exhaustion of a special limited supply of food, which cannot be restored, since it may be supposed that some particular bodily structure is altogether destroyed, as, for example, Peyer's patches may be in enteric fever. One objection to this view is, on the other hand, that living animal particles die with great rapidity after exit from the body, while the contagia do certainly last for some considerable time.[1]

(2) The particles have been conjectured to be of fungoid nature, and to simply grow in the body after being introduced *ab externo*. This view is supported by the peculiarities of the rapid and enormous growth of *fungi*, by their penetrative powers and splitting-up action on both starchy, fatty, and albuminoid substances, and by the way in which certain diseases of men and of animals[2] are undoubtedly caused by them. It is clearly a view which would explain many phenomena of the contagious diseases, and has been supported by the experimental evidence of Hallier and many others, who have believed either that they have invariably identified special *fungi* in some of these diseases, or that they have succeeded in cultivating fungi from particles of contagia. At the present time, however, the evidence of true, recognisable, and special *fungi* being thus discovered and grown, and forming the efficient causes, is very much doubted by the best observers. The *micrococci* of Hallier, supposed to be formed by the disintegration of the protoplasm of *fungi*, which Hallier considers can again develop to *fungi*, are looked upon by many as mere detritus.[3]

(3) The particles of contagia are thought to be of the nature of the *Schizomycetes*, *i.e.*, of that class of organisms which Nägeli has separated from the fungi, and which form the lowest stratum at present known to us of the organic world. They are termed *Bacteria*, *Bacilli*, *Microzymes*, *Microbes*, *Vibrios*, *Spirilla*, *Monads*, &c. Their relation to the *fungi*, or to the *Oscillarineæ*, to which they are perhaps more closely allied, is yet a matter of warm debate.

That these creatures are concerned in many diseases is clear. Lister's genius first brought their practical importance forward, and the later researches of Klebs, Recklinghausen, and others, have shown how great a part they play in the production of Septichæmia. The carbuncular disease of cattle and sheep (splenic apoplexy) is also intimately connected with *Bacilli;* and, if the observations of Coze, Feltz, and others are correct, the same is true of enteric fever. Ferdinand Cohn has asserted[4] that even the

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[1] A modification of this view, under the name of the Glandular Origin of Disease, is advocated by Dr B. W. Richardson, F.R.S. (*Address to the Sanitary Institute of Great Britain*, Leamington, 1877; *Nature*, No. 414, Oct. 4, 1877, p. 480). Admitting that the disease poison generally comes from without, he looks upon its action as catalytic, causing an altered glandular secretion or a change in the blood, the changed secretion reacting on the nervous centre supplying the gland or glands. He also conceives that during epidemic periods a strong nervous impression may have the same effect as the direct introduction of poison from without, so that the disease may occasionally arise spontaneously. He looks upon many diseases as hereditary, in the sense that the condition of the child resembles that of the parent, and will therefore be open to similar influences.

[2] Not only some skin and hair diseases of men and animals, and diseases of insects and fishes, are caused by the growth of fungi which fall on the surface of the body, or are drawn into the mouth, but internal diseases are caused by the growth of undoubted fungi, such as *Aspergillus*.

[3] The supposed fungus, which Klein (*Reports of the Medical Officer of the Privy Council*, new series, No. vi., 1875) thought he had discovered in the patches of typhoid ulceration, was shown by Creighton to be merely an altered condition of fibrine simulating an independent organism (see *Proceedings of the Royal Society*, June 15, 1876).

[4] Virchow's *Archiv*, Band iv. p. 229 (1872).

glistening particles of vaccine lymph; are *Bacteria*. *Bacteria* have been proved to cause disease of the intestinal mucous membrane, the uterus, the kidneys, and the heart, and they play some part in hæmorrhagic smallpox. *Bacilli* were found to be the active agents in the poisoning by ham at Welbeck. Klebs and Tommasi-Crudeli have shown the probability of malarial poisoning being due to a *Bacillus*. Still more recently, Koch has essayed, with apparent success, to connect phthisis with a similar organism, *Bacillus Tuberculosis*. Ransome has demonstrated its presence in the breath of phthisical patients.[1] The peculiar form of febrile disease observed at Aberdeen by Dr Beveridge was distinctly connected with the existence of minute organisms in milk.[2] The researches of Pasteur on fowl cholera and charbon have shown not only that those diseases are due to *Bacteria*, but that they can be prevented or modified by inoculation with cultivated virus. His later labours in the matter of hydrophobia have been in the same direction.

Yet in some of the epidemic diseases no *Bacteria* have been as yet demonstrated. In cholera, Lewis and Cunningham failed, in spite of the most persevering search, to find *Bacteria* (or *fungi*) in the discharges or blood. Koch, however, believed he had succeeded in connecting cholera with a so-called comma-shaped *Bacillus*, which he said he found in the intestinal discharges of cholera patients, as well as in the water of the tanks from which patients had drunk. The reports of Drs Klein and Heneage Gibbes confirmed the existence of such a structure under certain circumstances, but threw doubt upon its positive connection with cholera. A committee assembled at the Indian Office reported that they did not think the connection positively made out. Lewis showed that the so-called *commas* were segments of a *vibrio*, and that similar structures could be obtained from the mouths of healthy persons. Finkler and Prior, and Emmerich found similar bodies in cases of *cholera nostras*. Cultivations, however, showed some difference of life-history.

The reasons for attributing in many cases great influence to *Bacteria*, which are undoubtedly present, are obvious enough.

They are so widely spread in nature (in both air and water); their powers of growth, by division, are so wonderful; their food (ammonia, phosphates, and perhaps starches or sugars) is so plentiful; and their tenacity of life so great, that it is no wonder great consequence is now attached to them. Yet it is their very universality which is one of the strongest arguments against the view that they constitute the contagia of any of the specific diseases, and any one who considers the peculiar spread of the contagious diseases will admit the force of this objection. To meet this objection it has been surmised that they are not the contagia, but merely their carriers. This view has not been defined; but as the plasma of *Bacteria* is albuminoid, it may perhaps be taken to mean that while the *Bacteria* are usually harmless, their plasma may become, in certain cases, altered in composition, and then becomes poisonous in different specific ways. *Bacteria* feeding in the blood of a typhus patient will become nourished with morbid plasma, and thus, so to speak, it is diseased *Bacteria* which become dangerous. Another and more probable view is that there are benign *Bacteria* as well as malign, and that the latter cannot continue to exist in the presence of the former, in fact that they are crowded out. Some of the experiments of Fodor and Miquel seem to show this.[3]

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[1] *Proceedings of the Royal Society*, vol. xxxiv. p. 274 (1882).

[2] See note by Professor Ewart, *Proceedings of the Royal Society*, 1881, vol. xxxii. p. 492.

[3] For further information, see the "Address in Medicine," by W. Roberts, M.D., F.R.S., delivered at the Manchester Meeting of the British Medical Association, 1877 (*Brit. Med. Journal*, No. 867, 11th Aug. 1877, p. 168). Also Professor Tyndall's papers in the Royal

The belief which some entertain that *Schizomycetes* are the efficient agents of the contagious diseases has led to a number of experiments on the destruction of *Bacteria* by heat and by chemical agents, in the belief that the doctrine of disinfection was thereby elucidated. This could hardly be the case, unless we are certain that the *Bacteridia* are the contagia, which is not yet proved to be the case generally, however probable it may be. Disinfection must rest at present on its own experimental evidence.

The belief in the part played by *Bacteridia* has led also to much interest being taken in the discussion on ferments, and in the question of spontaneous generation, as it is imagined that a clue might thus be found to the origin, *de novo*, of the contagia. Mr Darwin's doctrine of Pangenesis has even been pressed into the discussion, though it rather makes the darkness greater than before. It is curious to find so practical a matter as that of disinfection brought into relation with some of the most subtle and controverted questions of the day; but the important bearing which the acceptance of one or other of these views would have on the practice of disinfection is evident.

The following are some of the pathogenic organisms which have been more or less accepted:—*Aspergillus Mycosis; Bacillus Anthracis* (splenic fever, malignant pustule, wool-sorter's disease); *B. Malariæ* (?); *B. Septichæmiæ* (experimental); *B. Lepræ; B. Tuberculosis* (the smallest of the *Bacilli*); organisms not exactly determined, but believed to be the causes of septic pneumonia and diphtheria; *Actinomyces* (Actinomycosis hominis); the *Micrococcus* of scarlatina (Klein); *Micrococcus* of vaccine; to these may be added, but doubtfully, the *Comma Bacillus* of Koch (cholera); the *Bacilli* of Finkler and Prior, and of Emmerich; the supposed microbe of enteric fever; and others. *Bacillus subtilis* and *ulna* have not been found in man or animals.

2. *The Media in which the Contagia are spread.*

Our knowledge of this point is far more defined, and may be thus summarised :—

The special and distinctive phenomena of each disease are usually attended with special implication of some part of the body, and it is especially these parts which contain the contagia. In these parts there is frequently rapid growth, and if the parts are on the surface, frequent detachment. The pus and epidermis of smallpox; the epidermis and the mouth and throat epithelium of scarlet fever, sore throat and diphtheria; the skin and bronchial secretions of measles; the stools containing the discharged detritus of Peyer's glands in enteric fever; the discharges of cholera; the discharges and eruptions of syphilis, glanders, farcy, and malignant pustule, are instances of this. In typhus fever the skin is greatly affected, and it is generally supposed that it is from the skin that the virus spreads, since this disorder is so easily carried by clothes; the same is the case with plague. In fact, those parts of the body which are the breeding-places of the contagious particles give off the poison in greatest amount. The portions of the body thus thrown off, and containing the contagia, may then pass into air, or find their way into water or food, and in this way be introduced by breathing, drinking, or eating, or through broken surfaces of the body.

The principles of disinfection ought evidently then to deal with the poisons, at their seats of origin, as far as these are accessible to us. It was the instinct

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Society's Proceedings and Transactions (see *Transactions of the Royal Society*, 1876, part i. p. 27); *Floating Matter in the Air*, by the same author; Nägeli's *Niedere Pilze;* Fodor's *Untersuchungen, op. cit.;* the works of Miquel, Klein, Cornil and Babes, and Crookshank.

of genius which led Dr William Budd to point out that the way to prevent the spread of scarlet fever is to attack the skin from the very first; to destroy the poison in the epidermis, or, failing that, to prevent the breaking up and passage into the air of the particles of the detached epidermic scales. Oily disinfectant inunctions of the skin, and the most complete disinfection of the clothing which touches the skin of the patient, are the two chief means of arresting the spread of scarlet fever. The rules for smallpox are almost identical, though it is more difficult to carry them out. In enteric fever the immediate destruction of all particles of poison in the stools by very strong chemical reagents, and the prevention of the poison getting into sewers or drinking water or food, are the measures obviously demanded by the peculiarities of this special disease.

The more completely these points are investigated, and the more perfectly the breeding-places in the body are known, the more perfect will be our means of disinfection.

3. *Effects of Heat as a Disinfectant.*

If the *contagia* are simply excessively minute portions of bioplastic particles, in Beale's sense, we may be sure they will be easily killed; a heat far below that of boiling water, and very weak chemical agents, destroy all signs of vitality in animal cells and molecules. We might, therefore, hope much from disinfection. *Fungi* in water are destroyed by a comparatively low heat; while in dry air *Penicillium glaucum* is not completely destroyed, according to Pasteur, till 127° C. (= 260° Fahr.), and *Oïdium aurantiacum* dies at about the same temperature. On the contrary, the Bacteroid bodies are often extremely stable. Lex found a temperature of 127° C. (or 260° Fahr.) insufficient to kill them, and after boiling them for half an hour they still showed vital movements; and in Calvert's experiments a heat of no less than 400° Fahr. (= 205° C.) was required to thoroughly destroy them, and some kinds seem unaffected even by strong acids and caustic alkalies. Bastian has, however, stated [1] that *Bacteria* and *Vibrios* are killed at a much lower temperature; his experiments show that a brief exposure to a temperature of 70° C. (= 158° Fahr.) either killed the germs of *Bacteria* or completely deprived them of their powers of multiplication. Dowdeswell found that the *Bacteria* of Septichæmia, both Pasteur's and Davaine's, were killed at 140° C. (= 284° F.)[2] Sanderson found that *Bacteria* in water are not developed in fluids heated to 366° Fahr. (= 185° C.) or even only boiled. Disinfection, if *Bacteridia* are to be destroyed, would be then a matter of much greater difficulty. Tyndall [3] has since pointed out what appears to be an explanation of the above discrepancies. He shows that, whilst prolonged boiling failed to sterilise an infusion, successive heatings for a short time, even below the boiling-point, were successful. The explanation proposed is, that during the period of latency the spores are in a hard state capable of resisting high temperature, but that just before the period of active germination, they become softened, and therefore amenable to the influence of heat. As, however, spores in various stages may exist in the same fluid, successive heatings are necessary so as to arrest each group at the proper time; but by repeating the heatings sufficiently often an infusion may be sterilised at a point below the boiling-point of water. This method of intermittent heating is now in general use for sterilising cultivating fluids. Important in all ways, this question of the

[1] *Proceedings of Royal Society*, No. 143, p. 224, March 1873.
[2] *Proceedings of Royal Society*, vol. xxxiv. p. 274, 1882. [3] *Ibid.*, No. 178, p. 569.

nature of contagia is especially so in a practical sense, viz., that of the easy or difficult destruction of these agents. It does not, however, follow that ordinary putrefactive *Bacteria* are identical with those which may be supposed to produce disease. It is probable that they are quite different, and that disease *Bacteria* are more easy destructible by heat at least. Klein says that *micrococci* of scarlatina are killed at 85° C. (185° F.).

Purification of Clothes and Bedding.—The best plan of doing this is certainly by the agency of heat. Dr Henry, of Manchester, after showing that vaccine matter lost its power if heated to 140° Fahr. (60° C.) for three hours, proposed to disinfect clothing by dry heat. He disinfected scarlet fever clothing by exposure to 212° Fahr. (100° C.) for one hour; woollen clothing from plague patients, after being heated twenty-four hours from 144° to 167° Fahr. (62° C. to 75° C.), was worn with impunity by fifty-six healthy persons for fourteen days.—Heat was largely used to disinfect clothing by the Americans in their civil war, both in the form of dry heat and boiling water. It is believed that the cessation of the plague in Egypt, after St John's Day, was due to the increased heat of the air; but possibly the hygrometric condition of the air may have more to do with this. It has also been surmised that the yellow fever poison is destroyed by an intense heat. Dr Shaw has collected the few facts which we know on this subject.[1]

Disinfecting Chambers, that is, hot-air chambers, into which clothing, linen, and bedding are put, are used. The usual arrangement is a furnace with the smoke shaft passing under or on one side of a brick chamber, and with a hot-air blast from a shaft running through or under the fire into the chamber itself, or into a passage below it, whence it passes into the chamber through a valve; an exit for the hot air is provided at the top of the chamber; the clothes are suspended in the chamber, at a little distance from the walls.

In other cases the bottom of the chamber is made of iron, and the smoke flue passes beneath it; the iron becomes red hot, and is covered with sand, to prevent the clothes taking fire. Hot air is then poured into the chamber in the same way. The disadvantage of the hot-air blast is the uncertainty and variation in the amount of heat.

Fraser has devised a good form of stove, in which high temperature and the use of sulphurous acid are combined. The articles are wheeled into the stove in the cart that brings them. Dr Ransom of Nottingham has devised a gas stove, viz., an iron box well covered with non-conducting material; in a channel leading to it a gas-jet burns; by means of a regulator (modified from Kemp's regulator) the heat is kept uniform day and night; the hourly consumption of gas is 9 cubic feet for a small stove, which is sufficient for the hospital at Nottingham.

Steam has also been used; and at Berlin a steam disinfecting chamber, proposed by Dr Esse,[2] is said to work well. This chamber is in the form of two iron cylinders of different diameters, one inside the other, and with walls strong enough to withstand the pressure of the steam; between the two cylinders steam enters from a neighbouring boiler, and heats the internal cylinder in which the clothes are suspended; at the top of the cylinder is a brass box which dips a little way down, and is pierced with holes at the bottom, so that the air of the inner cylinder can rise into it; in the box is a thermometer. The outer cylinder is covered with wood, and the top of the cylinder with felt, to economise heat; the steam, when it

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[1] *Trans. Soc. Science Assoc.* for 1864, p. 558.
[2] *Deutsche Vierteljahrsch. für öff. Gesundheitspflege,* Band iii. p. 534 (1871).

condenses in space between the cylinders, flows out by means of a valve which is lifted when the water reaches a certain point in the condenser. The clothes are introduced at the top, the lid of the cylinder being lifted up by a pulley; they are not allowed to touch the cylinder, but are suspended from wooden pegs. In an hour's time the heat can be brought to 90° R. (= 234°·5 Fahr., or 112° C.). Another apparatus has been contrived by Esse for mattresses. It is an iron case with a spiral steam pipe in the centre, which heats with compressed steam (two atmospheres).

A steam cylinder has also been used at the London Fever Hospital, for disinfecting the feathers used as bedding.

The best disinfecting chamber is that by Mr Washington Lyons, of Peckham. It is a cylinder, within which the clothes are placed, and superheated steam, gauged by pressure, driven into them. The steam is perfectly dry but it penetrates every part. This apparatus is in use in the Metropolitan Asylums Hospitals, and elsewhere.

The ordinary drying closet in a good laundry will sometimes give heat enough, but not always. A baker's oven can also be used on emergency.

The question of temperature has been much discussed. It is desirable to get as high a temperature as possible so as to ensure the destruction of disease poison. On the other hand, the temperature must not be too high, for fear of destroying the fabrics.

Ransom found that fine fabrics began to scorch at 255° to 260° Fahr. (124° to 133° C.). In some experiments, undertaken at the request of the Director-General, A.M.D.,[1] the following results were obtained:—*Woollen* fabrics changed colour after six hours' exposure at 212° Fahr. (100° C.), or after two hours at 220° Fahr. (114° C.); generally length of exposure and elevation of temperature were complementary. *Cotton* and *linen* showed signs of change of colour after six hours at 212° Fahr. (100° C.), or four hours at 220° Fahr. (114° C.). Professor E. Vallin,[2] of Val de Grâce, found that a piece of new white *flannel* was not more discoloured after two hours at 230° Fahr. (132° C.) than after one ordinary washing, and that even after three hours a piece already washed showed no change; two hours, however, at 240° Fahr. to 250° Fahr. (122° to 140° C.) showed distinct change. *Cotton* and *linen* did not change until they had been exposed for two hours to 257° Fahr. (153° C.). The strength of the material was not diminished (as shown by a dynamometer) until after two hours at 300° Fahr. (149° C.) *Horse-hair* became friable after exposure to heat, but this was chiefly an effect of drying, as it regains its ordinary condition after a short time (Vallin, Lake). In Ransom's stove the heat is arranged to be between 235° and 255° Fahr. (113° and 131° C.). After an accident at the Southampton Infirmary, where all the clothes, &c., in the chamber were consumed, a modification was introduced by Dr Ransom; a chain with a link of fusible metal is set free by the melting of the link as soon as 300° Fahr. (149° C.) are reached; this closes a door, shuts off the gas, and prevents any further rise of heat. In the Liverpool chambers 280° Fahr. (138° C.) has been registered, and no less than 380° Fahr. (194° C.) in the drying closet over the Cockle stove.

There is no doubt considerable variation in the temperature of different parts of the chamber, and the effects on fabrics vary according as they are placed on or near the floor and sides, or suspended in the centre or upper

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[1] By Dr F. de Chaumont, *Lancet*, 11th Dec. 1876.

[2] "De la Désinfection par l'air Chaud," *Mémoires de la Société de Médecine Publique et d'Hygiène Professionelle*, 1877.

parts. At the Southampton Infirmary, all bedding and clothing are exposed in the chamber after every occasion of use, the mean temperature being under 230° Fahr. (110° C.), but there is distinct deterioration of fabric, a loss incurred designedly in order to secure complete destruction of disease poison.

As before stated, we have no reason to believe that disease germs will resist a temperature of 220° Fahr. (114° C.), or even 212° Fahr. (100° C.), if completely and thoroughly exposed to it. Even when liquids, such as water or milk, have been infected, no case of disease has ever been traced to the use of such liquids after being *boiled.* It seems therefore unnecessary to carry the heat to excess, 220° Fahr. (114° C.) being in all likelihood sufficient, or even 212° Fahr. (100° C.) with some length of exposure. In the *Army Medical Regulations* (1885, 1093 *a*), exposure to a temperature of not less than 212° Fahr. (100° C.) for at least two hours is ordered.

Soaking and Boiling Clothes.—The boiling of clothes is not generally considered so good as baking, but still is very useful. It is desirable to add some chemical agent to the water, and chloride of lime is frequently used in the proportion of 1 gallon of the strong commercial solution to 20 or 30 gallons of water. Carbolic acid (1 part of pure acid and 2 parts of commercial acid to 100 of water) is also much employed. The German military regulations order the clothes to be laid for twenty-four hours in a solution of sulphate of zinc, in the proportion of 1 part to 120, or of chloride of zinc, in the proportion of 1 part to 240, and then to be washed with soap and water, if the clothes cannot be baked. Corrosive sublimate (1 : 1000) is now used. The routine Dr Parkes followed in the case of a large military hospital during war (Renkioi) was to receive all dirty clothes into a large open shed, and to plunge them at once into tubs of cold water with chloride of lime. After twelve to twenty-four hours' soaking, according to their condition, they were put into coppers and boiled, chloride of lime being again added to the water; they were then put into the washing machine, and then dried and baked in a dry closet, heated to the highest point that could be got—about 200° to 230° Fahr. (92° to 114° C.). If lice were very numerous, it was a good plan to bake the clothes before soaking; the lice were mostly killed, but some were only torpid, and were still living, after a temperature of probably 200° Fahr. (92° C.). They could, however, be shaken out of the clothes easily even if not dead.

Fumigating Clothes.—This is best done with sulphur, which may be used in the hot chamber, as in Fraser's oven, or the clothes are suspended in a small close chamber or large vat, and a large quantity of sulphur is set on fire, care being taken that the clothes are not burnt. Hair mattresses must be taken to pieces before fumigation if they be much defiled.[1]

4. *Effects of Chemical Agents.*

Although numerous experiments have been made upon this point, yet our knowledge still remains somewhat obscure. A large number of substances have been proposed, and many actually tried, with varying results. One cause of discrepancy has been the somewhat loose way in which the term *disinfectant* has been employed in cases where the action has been little more than *deodorant.* Chemical agents may be divided into—(*a*) those which actually destroy disease poison and minute organisms; (*b*) those which

[1] *Army Medical Regulations,* 1885, part 6, section v. paras. 1093-1102.

suspend vitality and propagation; and (c) those which merely deodorise, that is, destroy or mask smell. Even such a division cannot be carried out consistently, and all that we can say is, that some substances act powerfully as destroyers of disease poison and minute life, if used in sufficient quantity and degree of concentration; such substances are also generally deodorants. Other substances do not appear positively to destroy disease poison or minute life, but they certainly suspend its vitality for a time, and we may therefore use this interval of suspension advantageously by getting rid of the infected matter without danger in transit.

A further division of chemical agents might be into gaseous, liquid, and solid, and other divisions might also be suggested. Perhaps the most convenient plan will be to state the objects to be attained, and consider the agents which may be used.

Purification of the Air by Chemical Methods.

The great purifying actions of Nature are diffusion, dilution, transference by winds, oxidation, and the fall of rain. In houses the power of ventilation is the only safe method, but some effect can be produced by chemical ageucies in aid of veutilation.

The foreign matters in the air, which can be removed by chemical means, are carbou dioxide, hydrogen sulphide, ammonia (usually in the form of ammonium sulphide), and various organic substances, arising in an infinity of ways, some being odorous, others not, and of the physical and chemical nature of which little or nothing is known. Air purifiers are also used to check the growth of fungoid, infusorial, or bacterioid organisms. They are used in the form of solids or of liquids, which may absorb the substances from the air, or of gases which may pass into the air and there act on the gases or molecular impurities.

(*a*) *Solid Air Purifiers.*—Dried earth, quicklime, charcoal, and calcium and magnesium carbolates (phenates), a mixture of lime and coal-tar, are the most important.

Of these *charcoal* is the most effectual. It presents an immense surface, and has a very extraordinary power of separating aud absorbing gases and vapours from the atmosphere,[1] and oxidises rapidly almost every substance capable of it. Its action is not indiscriminate, but elective (A. Smith); when charcoal which has absorbed oxygen is warmed, it gives off CO_2 (A. Smith), a proof of its great oxidising power. Exposed to the air in bags or shallow pans, its action is rapid and persistent; its effect is especially marked with sewage gases, and with the organic emanations in disease. It also absorbs hydrogen sulphide. Its power of purifying air from organic emanations is really great, and can be employed in hospital wards with advantage.

Of the different kinds of charcoal, the *animal* charcoal has the highest reputation, and then peat. But the carbon left in the distillation of Boghead coal has been stated to be even better than animal charcoal. If vegetable charcoal be used, it should be rather finely powdered. The disinfecting qualities of charcoal on air scarcely lessen with time if the charcoal be kept dry. Charcoal filters to be placed before the mouth have been recommended by Stenhouse, and might be useful in cases of very impure air. Dried marly earth is much inferior to charcoal, but still can be employed in the absence of the latter.

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[1] Sennebier, quoted by Chevallier, *Traité des Désinfect.*, p. 146, and A. Smith.

Quicklime absorbs CO_2 and perhaps compounds of sulphur, and has been employed for that purpose.

Calcium and *magnesium carbolates* have also been used; as they give off carbolic acid, their action is probably chiefly in that way.

(*b*) *Liquid Air Purifiers.*—Solutions of *potassium permanganate* (Condy's red fluid), *zinc chloride*, and *lead nitrate* are sometimes used, being either exposed in flat dishes, or cloths are dipped in the solution and exposed to the air. They act only on the air which comes in contact with them, but in that way absorb a good deal of impurity. Condy's fluid, when well exposed to the air, seems to have a good purifying effect, and to lessen the close smell of ill-ventilated rooms, and it absorbs hydrogen sulphide, and so will also solution of nitrate of lead.

(*c*) *Gaseous Air Purifiers.*—The evolution of gases into the air is the most powerful means of purifying it independent of ventilation. The principal gases are *ozone*, *chlorine*, fumes of *iodine* and *bromine*, *nitrous*, *sulphurous*, and *hydrochloric acids*, *carbolic acid*, *tar fumes*, *acetic acid*, *ammonia*.

Ozone.—It has been proposed to disengage ozone constantly into the air of a room by heating a platinum wire by a Bunsen cell; by half immersing a stick of phosphorus in tepid water in a wide-mouthed bottle; or by mixing very gradually 3 parts of strong sulphuric acid and 2 parts of permanganate of potassium. This last method is that used by Dr Fox.[1] The amount of ozone can be measured by the common ozone paper, and the stopper put in if the tint is too deep. It is presumed it will then act as a powerful oxidising agency, and destroy organic matter, as it certainly removes the putrid effluvia of decomposing blood (Wood and Richardson). It was much used by Dr Moffat in cholera and cattle plague.

Chlorine.—Given off from chloride of lime, moistened with water or with dilute sulphuric acid, and placed in shallow vessels, or from chloride of soda, or evolved at once. Four parts by weight of strong hydrochloric acid are poured on one part of powdered manganese dioxide, or four parts of common salt and one part of manganese dioxide are mixed with two parts by weight of sulphuric acid and two of water, and heated gently. According to the size of the room, the actual weight of the substances taken must vary. Or two table-spoonfuls of common salt, two tea-spoonfuls of red lead, half a wine-glassful of sulphuric acid, and a quart of water are taken. Mix the lead and salt with the water, stir well, and add the sulphuric acid gradually. Chlorine is evolved, and is absorbed by the water, from which it is slowly driven out. It may be kept in a jar or stoppered bottle, left open as occasion may require.[2]

Chlorine decomposes hydrogen and ammonium sulphides at once, and more certainly than any other gas. It doubtless destroys organic matter in the air, as it bleaches organic pigments, and destroys odours, either by abstracting hydrogen, or by indirectly oxidising. Euchlorine, a mixture of chlorous acid and free chlorine, obtained by gently heating (by placing the saucer in warm water) a mixture of strong hydrochloric acid and potassium chlorate, has been also used instead of pure chlorine. It has been strongly recommended by Professor Stone, of Manchester, who has devised a special apparatus for its disengagement. He also uses it by placing fuming hydrochloric acid in a wine-glass, and adding a few grains of chlorate from time to time. In that way there is no danger of explosion, as sometimes is

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[1] *Ozone and Antozone*, p. 25.

[2] Medlock's *Record of Pharmacy and Therapeutics*, 1858, p. 20.

the case if a large quantity of chlorate is warmed with hydrochloric acid. The odour of euchlorine is more pleasant than that of chlorine; it acts as rapidly on iodide of potassium and starch paper, and appears to have a similar action on organic substances; it is probably inferior to pure chlorine, but the ease of development and its pleasanter smell are in its favour.

Iodine can be easily diffused through the atmosphere by placing a small quantity on a hot plate. Dr Richardson proposes to saturate a solution of peroxide of hydrogen with iodine, and to add 2½ per cent. of sea-salt; by "atomising" or "pulverising" the fluid by the little instrument used for this purpose, the air can be charged with iodine and sea-salt spray very readily. Iodine will decompose SH_2, and destroys, therefore, much odour. Its action was investigated by Duroy in 1854,[1] who showed that it is a powerful arrester of putrefaction. As it condenses easily, and does not diffuse everywhere like chlorine, it might be expected to be less useful than chlorine.

Bromine.—In the American civil war bromine was rather largely used as an aërial disinfectant; a solution of bromine in bromide of potassium is placed in saucers and exposed to the air; the vapour is, however, very irritating, and should not be disengaged in too large an amount.

Nitrous acid or *Nitrogen tetroxide* can be evolved by putting a bit of copper in nitric acid and a little water. The nitrogen dioxide which is given off takes oxygen from the air, and red fumes, consisting chiefly of nitrogen tetroxide or nitrous acid (NO_2), are formed.

The oxidising action of nitrous acid is very great on organic matter. It removes the smell of the dead-house sooner than any other gas. It is rather irritating to the lungs, and, in some persons, large quantities of it cause vertigo, nausea, and even vomiting.

The action of nitrous acid results from the ease with which it parts with oxygen to any oxidisable substance, being converted into nitrogen dioxide, which again at once combines with atmospheric oxygen, and so on.

Sulphurous acid or *Sulphur dioxide.*—Most easily evolved by burning sulphur. It decomposes hydrogen sulphide ($SO_2 + 2SH_2 = 3S + 2OH_2$), and also combines with ammonia. It has also been supposed to act powerfully upon organic matter (Graham), and probably does so if ammonia is not present. Guyton-de-Morveau, who studied the action of this acid, was of opinion that it completely disinfected miasms, and he gave some evidence on this point. It must be used in large quantity. The use of sulphur fires in times of epidemics has been recommended (Tuson).

Hydrochloric Acid.—The fumes of this acid were used by Guyton-de-Morveau, and at one time they were much employed, but the action of chlorine is so much more powerful that they are now seldom used.

Carbolic Acid.—This substance is given off when solid carbolic acid is placed in a saucer, or when the liquid acid and water are sprinkled about, or, still better, when one part of the acid and two of ether are allowed to evaporate. It is difficult to measure its action, as it decomposes solution of potassium permanganate, which cannot therefore be used as a measure of the organic impurity of air when carbolic acid vapours are present.

Dr Sansom[2] has shown that when the acid evaporates, 1 grain of carbolic acid is taken up, at different temperatures, by the following amounts of air, viz., by 320·75 cubic inches at 50° Fahr. (10° C.), by 159·44 cubic inches

[1] Chevallier, *Traité des Désinfect.*, p. 19.
[2] *The Antiseptic System*, by A. E. Sansom, M.D., 1871, p. 15.

at 60° Fahr. (15·5° C.), and by 93·75 cubic inches at 70° Fahr. (21° C.). Vaporisers for carbolic acid fumes have been made, by means of which carbolic acid falls, drop by drop, on a hot metal plate.[1] Dr Langstaff[2] invented a trough, containing flannel wetted with water and carbolic acid (1 part of acid and 20 of water), which is placed in the inlet ventilating tubes; he found that at a temperature of 57° Fahr. (14° C.), four ounces of water are taken up in twenty-four hours, and this will keep the air of a room, 22 feet × 10 and 11 feet high, thoroughly impregnated with the odour. Carbolic acid conceals all odours, though it will not destroy hydrogen sulphide if it exists; it lessens the rapidity of putrefaction of animal substances suspended in a room, and they also dry faster, according to Langstaff. It also rapidly arrests the growth of fungi, though it will not completely destroy them; for example, some fresh fæcal matter, free from urine, was put in a bottle, and air washed in strong sulphuric acid drawn over it; fungi appeared rapidly on the fæcal matter. Air impregnated with carbolic acid was then passed over the fungi; they became discoloured, brownish, and apparently died; but on again substituting washed air, they revived. The rapid destruction, and the as rapid recovery and regrowth, could be repeated many times, and showed that the carbolic acid air had withered without actually killing the fungi.

The small growing cells suspended in the air are also stopped in their growth (according to Trautman); and, in fact, the action of carbolic acid may be said to be restraint of putrefaction and limitation of growth of low forms of aërial life.[3] The exact mode in which it acts is uncertain. When in some quantity, it coagulates albumen; and it has been supposed to be in this way that it restrains putrefaction.[4]

A mixture of 1 part of carbolic acid and 9 of vinegar, and a little camphor, has been used as a disinfectant (deodorant?) in cabins on board ship.

Coal-tar and Bitumen Fumes.—This is an old plan much used in the last century; the fumes contain carbolic and cresylic acids with other substances, and, it is presumed, have the same effect as carbolic acid. The substance employed by Süvern, and which has had some reputation in Germany, owes its success as an air-purifier to the fumes of coal-tar.

Vinegar and Ammonia.—The vapour of vinegar is an old remedy, and was much employed by Howard in the purification of jails; the efficient agents were probably heat and ventilation, which Howard made use of at the same time. The vinegar would, of course, neutralise any ammoniacal vapours which might be in the air; whether its action would extend beyond this is doubtful.[5]

The vapour of ammonia would not *a priori* seem likely to be a purifier, though, as it restrains decomposition in solid matters, its vapour may have an effect in the air. Winter Blyth[6] found it reduced *bacteria* colonies in sewage by 97 per cent.

It will be observed that the chief gases attacked by the air-purifiers are hydrogen and ammonium sulphide, which are easily destroyed by several agents, especially by chlorine, iodine, and sulphurous acid gas.

Purification of Rooms after Infectious Diseases.—In addition to thorough

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[1] Savory and Moore's vaporiser is figured by Sansom.
[2] *Hospital Hygiene*, by Charles Langstaff, M.D., 1872, p. 20.
[3] Lemaire, Crookes, Sansom, and others.
[4] Various other hydrocarbons probably act in the same way, as, for instance, the terebene proposed by Dr Bond of Gloucester, Jeyes' Perfect Purifier, and Little's Soluble Phenol.
[5] It may perhaps delay putrefaction and the growth of minute organisms.
[6] *Proceedings of the Royal Society*, vol. xxxix. p. 272.

cleansing of all wood-work with soft soap and water, to which a little carbolic acid has been added (1 pint of the common liquid to 3 or 4 gallons of water), and to removal and washing of all fabrics which can be removed, and brushing of the walls, the room should be fumigated for three hours with the fumes of either sulphurous or nitric acids. Both of these are believed to be superior to chlorine, especially in smallpox. All doors and windows and the chimney being closed, and curtains taken down, sulphur is put in a metallic dish, a little alcohol is poured on it, and it is lighted. The proportions should be 1 ℔ of sulphur for every 1000 cubic feet of space; and in a long room it is best to have the sulphur in two or more places. The amount ordered in the army is ½ ℔ for 1000 cubic feet.[1] After three hours the doors and windows should be opened, and kept open for twenty-four or thirty-six hours.

Lethcby gives a much larger proportion, viz., ½ ounce for every ten cubic feet. Even this is not an excessive amount. The quantity given above yields little more than 1 per cent. to the quantity of air. Thus—1 ℔ of sulphur produces 11·7 cubic feet of sulphurous acid gas, and this diluted with 1000 cubic feet of air gives only 1·17 per cent. Half an ounce of sulphur yields 0·366 of a cubic foot of the gas, and this for 10 cubic feet of air gives 3·66 per cent. Baxter found that 0·194 to 1 per cent. destroyed the reproductive power of septic microzymes in an albuminous or aqueous medium, but with 0·58 per cent. the poison of infective inflammation was still active. Vaccine was destroyed after ten minutes' exposure to an atmosphere *saturated* with SO_2, whilst chlorine or carbolic acid took 30 minutes' exposure. He concludes that for aërial disinfection SO_2 is the most convenient, but that the air should be *saturated* with it.

A lamp has been proposed by Messrs Price & Co., in which disulphide of carbon is burned. This seems, from experiments made at Netley by Professor Macdonald to be efficacious, but the extreme inflammability of the substance may be a source of danger. An ounce burned in 53 cubic feet arrested the movements of putrefactive *Bacteria* in a meat infusion in a saucer; it also made the infusion acid, but after some hours *Bacteria* were again in active motion. The amount of SO_2 evolved in the air was 1·16 per cent.

In white-washed rooms the walls should be scraped, and then washed with hot lime to which carbolic acid is added.

Mortuaries and dead-houses are best purified with nitrous acid or chlorine.

It ought to be clearly understood that anything like effectual *disinfection* is only possible by fumigation, when the air is rendered irrespirable for the time. Therefore any attempt whilst a room is in actual occupation can only be successful in deodorising,—experiment having shown that minute organisms are not destroyed by anything short of poisonous doses which would prove fatal to man or the higher animals. If, however, the germs of disease are (as is suspected) much more vulnerable than ordinary putrefactive *Bacteria*, partial fumigation, such as may be employed in a sick-room, may do some good. Even the deodorisation alone will be an advantage, but it is well not to depend too much upon it as a *disinfectant*, and so permit it to engender a false security, or allow it to interfere with complete and perfect ventilation.

With regard to the effect of chemical reagents on low forms of vegetable and animal life, the works of Sansom,[2] of Dr Dougall,[3] and the papers of

[1] Army Medical Regulations, 1885, Appendix 7, p. 274.
[2] *The Antiseptic System*, by A. E. Sansom, M.D., 1871.
[3] *On the Relative Power of various Substances in Preventing the Germination of Animalculæ*, by John Dougall, 1871.

Calvert[1] may be consulted; it need only be mentioned here that, according to Dougall,[2] the most powerful agents in destroying "animalculæ" are the following substances:—Sulphate of copper, chloride of aluminum, chromic acid, and dichromate of potassium, dichloride of mercury, benzoic acid, bromal hydrate, chloral hydrate, hydrocyanic acid, alum, hydrochlorate of strychnia, ferrous sulphate, arsenious acid, picric acid, and others which are less efficacious.

Picot[3] has stated that silicate of soda, even in very small quantity, arrests putrid fermentation and retards other fermentations, and is very useful in the treatment of blennorhagic urethral discharge in women. It also opposes the transformation of glucose and of the glycogenous matters of the liver. If silicate of soda has such an effect, may not some of the other silicates be also active in this way, and may not the antiputrescent power of some soils be thus produced? Lex found the movements of *Bacteria* to be best arrested by chloroform, carbolic acid, prussic acid, and strong solutions of quinine, in the order named. Dr O'Nial, C.B. (Surgeon-General), made many experiments on the time of appearance of *Bacteria* in extract of meat and other menstrua.[4] He found, like Dougall, the potassium dichromate to be the most powerful agent in preventing the appearance of *Bacteria*, and after it, but far below, is carbolic acid, yet neither was quite efficacious. The sodium disulphite was found to be of no value, and permanganate of potassium, though a good deodorant, had scarcely any restraining effect on the formation of *Bacteria*. Commercial chlor-alum was of little use, but a strong solution of chloride of aluminum was fairly effectual. The paper must be consulted for many details, but it shows clearly how little *Bacteria* can be influenced by our present modes of using these "chemical disinfectants." See also Baxter's paper.[5]

From a number of experiments made at Netley by Drs M'Donald, Notter, and de Chaumont,[6] the conclusions arrived at were that disinfectants required to be in poisonous quantity before they affected low forms of life, such as *Bacteria*. Similar conclusions have been arrived at by Lebon.[7] At the same time, he points out that there is little or no parallelism between action on ordinary *Bacteria* and disinfection. Thus potassium permanganate is a disinfectant, but has little action on *Bacteria*; alcohol, on the other hand, prevents the development of the latter, but is no disinfectant.

An elaborate inquiry by Mr Winter Blyth into the power of disinfectants, by means of cultivation, is given in detail in the *Proceedings of the Royal Society*, vol. xxxix., October 1885. He finds that absolute alcohol 60 per cent. disinfects, but absolute amyl alcohol, pure ether, chloroform, and carbon disulphide merely delay growth. Phenol disinfects at 15°·5 C. (= 60° F.) with a strength of 0·5 per cent., whilst at 35°·5 C. (= 96° F.) 0·25 per cent. is efficacious. Cresol at either temperature disinfects at 0·25 per cent. The pyridine bases are efficacious at varying strengths (3 per cent. and under), but especially at the higher temperature. Tobacco smoke (which contains bases of the pyridine series) was found to disinfect. Strychnine, brucine, quinine, and atropine are efficacious at 0·25 to 0·50 per cent. Morphine, even at 1·0 per cent. has no effect. Ferrous sulphate merely delays growth; potassic permanganate must be of at least 1 per

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1 *Proceedings of the Royal Society*, vol. xx. p. 185.
2 *Op. cit.*, table, p. 6.
3 *Comptes Rendus*, Dec. 1872.
4 *Army Medical Department Report* for 1871, vol. xlii. (1873).
5 *Reports of the Medical Officer of the Privy Council and Local Government Board*, new series, No. vi. p. 216.
6 Report on Hygiene, *Army Medical Reports*, vol. xx., 1880.
7 *Comptes Rendus*, Juillet 1882, p. 259.

cent. strength, and even then its effect may be arrested by some innocuous organic matter reducing it. Chlorine, bromine, and iodine disinfect completely at 0·01 per cent., the order of strength being as stated. All the above experiments were made on *Bacterium termo.*

5. *Disinfection in various Diseases.*

Exanthemata, Scarlet Fever, and Rötheln.—The points to attack are the skin and the throat. The skin should be rubbed, from the very commencement of the rash until completed desquamation, with camphorated oil, or oil with a little weak carbolic acid. The throat should be washed with Condy's fluid, or weak solution of sulphurous acid. Clothes to be baked, or to be placed at once in boiling water, to every gallon of which 2 ounces of commercial chloride of lime, or 1 ounce of sulphate of zinc, or ½ fluid ounce of chloride of zinc, is added. The clothes should not be washed at a common laundry.

In this, as in all cases, there can be no use in using aërial disinfectants, unless they are constantly in the air, so as to act on any particle of poison which may pass into the atmosphere; aërial disinfectants are therefore inapplicable to a sick room while occupied.

Smallpox.—The skin and the discharges from the mouth, nose, and eyes are to be attacked. There is much greater difficulty with the skin, as inunction cannot be so well performed. But smearing with oil and a little carbolised glycerine, or in difficult cases applying carbolised glycerine to the papules and commencing pustules, might be tried. The permanganate and sulphurous acid solutions should be used for the mouth, nose, and eyes. The clothing should always be baked before washing, if it can be done. The particles which pass into the air are enclosed in small dried pieces of pus and epithelial scales; and Bakewell, who has examined them, expresses great doubt whether any air-purifier would touch them.

Measles.—Oily applications to the skin, and chloride of zinc or of aluminum in the vessels receiving the expectoration, appear to be the proper measures.

Typhus (*exanthematicus*).—Two measures seem sufficient to prevent the spread of typhus—viz., most complete ventilation and immediate disinfection and cleansing of clothes. But there is also more evidence of use from air-purifiers than in the exanthemata. The nitrous acid fumes were tried very largely towards the close of the last century and the beginning of this, in the hulks and prisons where Spanish, French, and Russian prisoners of war were confined.[1] At that time, so rapidly did the disease spread in the confined spaces, where so many men were kept, that the efficacy even of ventilation was doubted, though there can be no question that the amount of ventilation which was necessary was very much underrated. Both at Winchester and Sheerness the circumstances were most difficult; at the latter place (in 1785), in the hulk, 200 men, 150 of whom had typhus, were closely crowded together; 10 attendants and 24 men of the crew were attacked; 3 medical officers had died when the experiments commenced. After the fumigations, one attendant only was attacked, and it appeared as if the disease in those already suffering became milder. In 1797 it was again tried with success, and many reports were made on the subject by

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[1] It was used at Winchester in 1780 by Carmichael Smith, and again at Sheerness in 1785. Smith published several accounts.—*An Account of the Experiment made at the desire of the Lords Commissioners of the Admiralty*, by J. C. Smith, 1796.

army and naval surgeons. It was subsequently largely employed on the Continent,[1] and everywhere seems to have been useful.

These facts lead to the inference that the evolution of nitrous acid should be practised in typhus fever wards, proper precautions being taken to diffuse it equally through the room, and in a highly dilute form.

Hydrochloric acid was employed for the same purpose by Guyton-de-Morveau, in 1773, but it is doubtless much inferior to nitrous acid. Chlorine has been also employed, and apparently with good results.[2]

In typhus it would seem probable that the contagia pass off constantly by the skin; at least, the effect of ventilation, and the way in which the agent adheres to body linen, seems to show this. The agent is not also enclosed in quantities of dried discharges and epidermis, as in the exanthemata, and is therefore less persistent, and more easily destroyed, than those cases. Hence possibly the greater benefit of fumigations, and the reason of the arrest by ventilation. The clothes should be baked, steeped, and washed, as in the exanthemata.

Bubo Plague.—The measures would probably be the same as for typhus.

Enteric (Typhoid) Fever.—The bowel-discharges are believed to be the chief, if not the sole, agents in spreading the disease; effluvia from them escape into the air, and will adhere to walls, and retain power for some time, or the discharges themselves may get into drinking water. Every discharge should be at once mixed with a powerful chemical agent; of those, chloride and sulphate of zinc have been chiefly used, but sulphate of copper (which Dougall found so useful in stopping the growth of animalculæ), chloride of aluminum,[3] nitrate of lead, carbolic acid,[4] or mercuric dichloride. Ferrous sulphate is not to be relied upon, according to Winter Blyth. After complete mixing, the stools must be thrown into sewers in towns; but this should never be done without previous complete disinfection; Winter Blyth shows that the shorter the time the disinfectant acts the less the disinfection. In country places they should be deeply buried at a place far removed from any water supply; they should never be thrown on manure heaps or into middens, nor into earth closets, if it can possibly be avoided. The best plan would be to burn them. As the bed-clothes and beds are so constantly soiled with the discharges, they should be baked, or if this cannot be done boiled immediately after removal with sulphate or chloride of zinc.

Cholera.—There can be little doubt that the discharges are here also the active media of conveyance of the disease, and their complete disinfection is a matter of the highest importance. It is, however, so difficult to do this with the immense discharges of cholera, especially when there are many patients, that the evidence of the use of the plan in the last European epidemic is very disappointing.

The ferrous sulphate (green vitriol), which has been strongly recommended by Pettenkofer as an addition to the cholera evacuations, was fully tried in 1866 at Frankfurt, Halle, Leipzig, in Germany, and at Pill, near Bristol,[5] and in those cases without any good result. In other places, as at Baden, the benefit was doubtful. It seemed to answer better with Dr Budd and Mr Davies at Bristol, but other substances were also used, viz., chlorine

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[1] Chevallier, *Traité des Désinfectants,* pp. 39, 40.

[2] *Ibid.*, pp. 14, 15.

[3] In speaking of chloride of aluminum, reference is always made to the strong solution, and not to the commercial "chlor-alum," which, though useful in various ways, is yet a weak solution.

[4] Or a mixture of two or more (Budd). Be lavish (says Budd) in the use of chemicals, rather than run the terrible risk of failing by default.

[5] Tibbets, *Medical Times and Gazette,* October 1867.

gas in the rooms, and chloride of lime and Condy's fluid for the linen. On the whole, it seems to have been a failure.[1] Ferric sulphate, with or without potassium permanganate, has been recommended by Kühne, instead of ferrous sulphate, but there does not appear to be any evidence on the point. Carbolic acid was largely used in England in 1866, and appeared in some cases to be of use, as at Pill, near Bristol, and perhaps in Southampton. It failed at Erfurt, but, as it is believed the wells were contaminated by soakage,[2] this is perhaps no certain case. Chloride of lime and lime were used at Stettin without any good result, and, on the whole, it may be said that the so-called disinfection of the discharges of cholera does not seem to have been attended with very marked results. At the same time, it cannot be for a moment contended that the plan has had a fair trial, and we can easily believe that unless there is a full understanding on the part of both medical men and the public of what is to be accomplished by this system, and a conscientious carrying out of the plan to its minutest details, no safe opinions of its efficacy or otherwise can be arrived at. It would be desirable to try the effect of chromic acid or potassium dichromate. Corrosive sublimate would probably be the best chemical reagent, but burning would be the best of all.

With regard to air-purifiers, little evidence exists. Chlorine gas, diffused in the air, was tried very largely in Austria and Hungary in 1832, but without any good results. Nitrous acid gas was used at Malta in 1865, but apparently did not have any decided influence, although Ramon de Luna has asserted that it has a decided preservative effect, and that no one was attacked in Madrid who used fumigations of nitrous acid. But negative evidence of this kind is always doubtful. Charcoal in bulk appears to have no effect; Dr Sutherland saw a ship's crew severely attacked, although the ship was loaded with charcoal.

Carbolic acid vapour diffused in the atmosphere was largely used in 1866 in England; the liquid was sprinkled about the water, and sawdust moistened with it was laid on the floors and under the patients. The effect in preventing the spread of the disease was very uncertain. The lighting of sulphur fires in infected districts has been recommended in India.

Yellow Fever.—In this case the discharges, especially from the stomach, probably spread the disease, and disinfectants must be mixed with them. Fumigations of nitrous acid were employed by Ramon de Luna,[3] and it is asserted that no agent was so effectual in arresting the spread of the disease.

Dysentery.—It is well known that dysentery, and especially the putrid dysentery, may spread through an hospital from the practice of the same close stool or latrines being used. As long ago as 1807 fumigations of chlorine were used by Mojon,[4] to destroy the emanations from the stools,

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[1] In Dr Parkes' experiments on sewage putrefaction (*Army Med. Reports*, vol. viii. p. 318), ferrous sulphate had very little action in preventing putrefaction, and the Committee of the Berlin Medical Society declined to recommend it for cholera, as they found it did not prevent fermentative action.

[2] *Ninth Report of the Medical Officer to the Privy Council.*

[3] *Ann. d'Hygiène*, April 1861.

[4] His words, as quoted by Chevallier, are interesting:—"The dysentery became contagious in the hospital at Genoa; almost all the sick in my division, nearly 200, were attacked; and as we know that this disease, when contagious, is communicated ordinarily from one person to another by the abuse which exists in all hospitals of making the same latrines serve for all the sick of a ward, I wished to see if fumigations of chlorine had the power of destroying these contagious exhalations. I therefore caused fumigations to be used twice daily in the latrines, and, in a few days, I was able to destroy that terrible scourge which already had made some victims."

and with the best effects. The chlorine was diffused in the air, and the stools were not disinfected; but this ought to be done, as in enteric fever, and especially in the sloughing form. It is probable that carbolic acid in large quantity would be efficacious.

With respect to *Erysipelas*, *Diphtheria*, *Syphilis*, *Gonorrhœa*, *Glanders*, and *Farcy*, local applications are evidently required, and carbolic acid in various degrees of strength, and the metallic salts, are evidently the best measures.[1]

Cattle Plague.—The experiments made by Mr Crookes on the disinfectant treatment of cattle plague with carbolic acid vapour have an important bearing on human disease. Although the observations fall short of demonstration, there are grounds for thinking that when the air was kept constantly filled with carbolic acid vapour, the disease did not spread. So also euchlorine was employed in Lancashire by Professor Stone, of Manchester, and with apparent benefit. Dr Moffat employed ozone (developed from phosphorus exposed to the air), and he believes with benefit.[2] As such experiments are very much more easily carried out on the diseases of animals than on those of men, it is much to be wished that the precise effect of the so-called disinfectants should be tested by continuing the experiments commenced by Mr Crookes, not only in cattle plague in the countries where it prevails, but in epizootic diseases generally.

Among other substances which may be used are *Jeyes' Perfect Purifier*, and *Little's Absolute Phenol*, both coal-tar preparations; *Sporokton*, a concentrated solution of sulphurous acid; and many others.

6. *Deodorisation of Sewage.*

A very great number of substances have been added to sewage for the purpose of preventing decomposition and retaining the ammoniacal compounds.

1. *Charcoal*, which soon, however, gets clogged and loses its power; it is not nearly so useful when used in this way as in the purification of air. When in relatively large quantity it decomposes the ammonia and sets nitrogen free, and so diminishes the agricultural value. Sillar's preparation (A, B, C deodorant) is a mixture of animal charcoal, blood, clay, and alum refuse. Under the name of native guano, the resulting product seems to be of value. Messrs Weare & Co.'s is also a charcoal process. *Patent Porous Carbon*, a substance prepared from Devonshire lignite, clay, and iron, is used at Southampton to the extent of 4 grains per gallon. The solid matter is deposited, and a moderately good effluent discharged.

2. *Dry Earth*, especially humus, and marly and clayey soils; the effect is similar to that of charcoal, but it is not so soon clogged. Bird's preparation is ferruginous clay, moistened with sulphuric acid, and then dried and pulverised.

3. *Quicklime* is sprinkled over the solid excreta, or quicklime and water added to sewer water, till a deposit occurs, leaving a clear fluid above. This is a very imperfect method, and the solid deposit has little or no value as a manure.

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[1] Davaine finds iodine most powerful in destroying the infection of malignant pustule, $\frac{1}{12000}$th part being effectual. It may be injected into the skin without injury (*Comptes Rendus*, Sept. and Oct. 1873). See also Report on Hygiene, *Army Med. Reports*, vol. xiv., in which its use in snake bite is suggested.

[2] *On Meteorology in reference to Epidemic and Sporadic Cholera*, by F. Moffat, M.D., Hawarden, 1868.

From 15 to 16 grains of quicklime are enough for 1 gallon of sewage, or 20 cwt. per million gallons. At Leicester 580 tons of quicklime were used per annum for 4,700,000 tons of sewage. The process has now been discontinued there, but is still partially employed at Birmingham and elsewhere.

Hanson's process consists in the use of slaked lime and black ash refuse, or the soda and tank waste from the alkali works, mixed with sulphuric acid.

4. Cheap salts of *alumina*, and then lime, or alum sludge, lime, and waste animal charcoal (Manning), or zinc and charcoal (Stothert's process), A, B, C (Sillar's process), chloride of aluminum (chlor-alum).

The alumina precipitated by the lime forms a very bulky precipitate, well suited to the entanglement of suspended matters. The clearance of the sewage is more perfect than with lime alone, but otherwise the process and the objections are the same, and the cost is greater. The whole of the phosphoric acid is precipitated as aluminum phosphate. To a gallon of sewage water there should be added $73\frac{1}{2}$ grains of aluminum sulphate, $3\frac{1}{2}$ grains of sulphate of zinc, $73\frac{1}{2}$ grains of charcoal, and $16\frac{3}{4}$ grains of quicklime.

Chlor-alum is a weak solution of chloride of aluminum; it is not a very powerful deodoriser, and must be used in large quantity, but its cheapness and want of poisonous properties[1] are recommendations, and when in sufficient amount it is effectual. It is efficacious against ammonia, but not against hydrogen sulphide; it acts moderately against fæcal odour.

5. *Chloride of Lime* is most powerful as a deodorant and also as a steriliser, especially at a high temperature; even at the ordinary temperature of 60° F. it reduced the colonies of *Bacteria* by 99·9 per cent. *Chloride of Soda* is similar in action, but is more soluble and throws down no deposit. Holmes' *Ozone Fluid* is simply a very strong solution of chloride of soda.

6. *Magnesium Superphosphate and Lime-Water* (Blyth's patent).—The idea was to add a substance which, in addition to deodorising, might be useful as a manure, and it was thought that a double phosphate of magnesium and ammonium would be thrown down; but this salt is sufficiently soluble in water, especially when the water contains chloride of sodium, to render this expectation incorrect. This method has been practically found to be useless, and to be more costly than any other plan.

7. *F. Hille*,[2] whose process was in use at Wimbledon, the town of Aldershot, and elsewhere, uses a mixture of lime, tar, and salts of magnesium for defæcating and deodorising the sewage. The effluent water is then passed through artificial filters, or used for irrigation purposes. This plan has been well spoken of by Major Flower[3] and others, and it appears to be moderate in cost compared with most other processes. At Wimbledon now the lime process is used, the sludge compressed into cakes, and the liquid passed over land.

8. *Iron Perchloride.*—When this salt is added to sewage, a precipitate of ferric oxide is caused by the ammonium carbonate (which forms so rapidly in sewage), and carries with it all the suspended matters of the sewage. A clear fluid remains above. The hydrogen sulphide falls in the precipitate

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[1] In some samples a considerable amount of lead was at one time found, but by improved manufacture this (it is said) has since been remedied.

[2] System—F. Hille, *Sewage Disinfecting and Filtration Process*, 2nd edition, 1876.

[3] Sewage Treatment, more especially as affecting the pollution of the River Lea, a paper contributed to the *Sewage Conference held by appointment of the Council of the Society of Arts*, in May 1876, by Captain L. Flower, Sanitary Engineer, Lea Conservancy Board, &c.

as iron sulphide. As the sulphide of iron tends to form ferric oxide, sulphur being let free, it has been conjectured by Hofmann that an oxidising effect from the oxide may follow the first action.

Both precipitate and supernatant liquid are free from odour.

This substance has been tried at Croydon and Coventry. From 14 to 29 grains per gallon of sewage are necessary for London sewage; for Croydon sewage from 5 to 15 grains were necessary. One gallon of liquid perchloride was sufficient for 15,000 gallons of sewage (Hofmann and Frankland).

The perchlorides of iron can be manufactured by dissolving in hydrochloric acid peroxide of iron, the different iron ores, refuse oxide of iron from sulphuric acid works, iron rust in foundries, &c. Another plan is to take equivalent proportions of common salt, sulphuric acid, iron rust, and water, so that chlorine, when disengaged, shall combine with the iron. A hard yellowish, not very deliquescent substance, containing 26 per cent. of perchloride of iron, is formed, which can be transported to any distance. The price, if made in this way, is £2, 7s. per ton (cost of labour not included) in England.

The perchloride acts both on hydrogen and alkaline sulphides, in both cases setting free sulphur. In sewage its ordinary action is on ammonium sulphide. Winter Blyth found 16·4 per cent. give a moderately successful result, but it seemed less efficacious than ferrous sulphate.

Objections have been made to the perchloride, as it contains arsenic; but the amount of this is small, and as it falls with the deposit it is never likely to be dangerous.

9. *Lueder and Leidloff's Powder* consists (according to Leuchtenberg's analysis) of ferric sulphate, 36 per cent.; ferrous sulphate, 16; free sulphuric acid, 4; calcium sulphate and other substances, 44. It has been highly commended, but, from experiments made at Netley, it does not seem very powerful.

10. *Lead Nitrate*, or *Ledoyen's Fluid*, is made by dissolving 1 ℔ of litharge in about 7 ounces of strong nitric acid and 2 gallons of water; a little of the water is mixed with the litharge; the acid is gradually added, and then the rest of the water. This quantity will deodorise a moderate-sized cesspool. It acts rapidly on hydrogen sulphide, and can be depended upon for this purpose.

11. *Mercuric Chloride* (corrosive sublimate) has been tried, and shown by Winter Blyth (*loc. cit.*) to be very powerful at strengths of from 0·1 to 0·5 per cent. It is a question whether its use on a large scale might not be attended with danger. It is, however, used abroad for various purposes, and in Russia for flushing the bilges of ships.

12. *Zinc Chloride.*—Burnett's fluid contains 25 grains to every fluid drachm; 1 pint is added to a gallon of water (1 to 8). It is usually said to decompose hydrogen sulphide until the solution becomes acid, when its action ceases; but Hofmann finds that it does not act on free hydrogen sulphide, but on ammonium sulphide, forming zinc sulphide and ammonium chloride. It destroys ammoniacal compounds and organic matter. The sulphates of zinc and copper decompose free hydrogen sulphide, with formation of metallic sulphide and water. Winter Blyth found zinc chloride very powerful.

Burnett's fluid delays decomposition in sewage for some time; but a very peculiar odour is given out, showing that some change is going on. A good effect is produced on hydrogen sulphide by a mixture of zinc and ferrous sulphates (Larnaudès' mixture), which also lessens for the time the peculiar sewage smell.

13. *Zinc Sulphate.*—This forms part of the Universal Disinfecting Powder[1] (Langston-Jones' patent), along with Cooper's salts, viz., calcium and sodium chlorides. This powder has the advantage of being inodorous, but it is not a strong deodorant. It, however, gets rid of fæcal odour to some extent, and is efficacious against H_2S.

14. *Potassium permanganate* prevents putrefaction for a short time, and removes the odour from putrefying sewage, but it requires to be used in large quantity. In a strength of 1 per cent. Winter Blyth found it very powerful at ordinary temperatures, and at 96° F. (35°·5 C.) it perfectly sterilised sewage. *Sodium manganate* has been tried, with and without lime, the success depending upon the quantity used.

15. Preparations from *coal-tar; carbolic acid* (phenol or phenic acid, or phenyl-alcohol (C_6H_6O)); coal tar creasote, and cresylic acid (cresol or cresyl-alcohol (C_7H_8O)), in various admixtures.[2] These substances are all excellent sewage deodorants and arresters of putrefaction.

The last few years have seen an extraordinary development in the manufacture of these substances. Phenol or carbolic acid is now obtained in great purity, and is sold in crystals, and also in a liquid form. All the preparations may be conveniently classed under the three divisions of crystals, liquids, and powders.

(*a*) *Crystals.*—Carbolic acid, more or less pure, is the only substance under this head; it is so slightly soluble in water (only in the proportion of 5 per cent.) that it is not so useful as a deodorant as the impurer kind. When mixed with sewage it acts slowly and not so perfectly as the impurer kinds. When exposed to the air it liquefies, and is slowly given out into the air, and is then supposed to be useful as an air purifier.

(*b*) *Liquids.*—Carbolic acid, more or less impure, dissolved in water, simply, or with a little alcohol and cresylic acid (cresol), forms the liquid carbolic acids. In the market they are found almost colourless, or highly coloured. The various liquids contain from 10 to 90 per cent. of phenol. Cresol, though crystalline and colourless when pure, is usually found in the market as a dark liquid. Some of it, no doubt, exists in most samples of carbolic acid. Owing probably to the way they mix at once with the sewage, the liquid acids are more deodorant than the crystallised acid, and restrain putrefaction for a long time. Carbolic acid, however, does not act on hydrogen sulphide, though it will restrain the processes which produce it.

Samples of so-called carbolic acid are sold, which are only impure tar oils, and almost destitute of deodorising power. Sometimes a nauseous sulphur compound is also present.

Mr Crookes[3] gives the following rules in order to determine the presence of the tar oils:—

"Commercial carbolic acid is soluble in from 20 to 70 parts of water, or in twice its bulk of a solution of caustic soda, while oil of tar is nearly

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[1] Analysis (de Chaumont)—

Water,	7·40
Calcium and sodium chlorides,	73·20
Zinc sulphate,	14·26
Insoluble,	5·20
Total,	100·06

To later samples some calcium borate was added.

[2] It is perhaps unfortunate that phenol and cresol, which are rather alcohols than acids, should have been termed carbolic and cresylic acids. If the terms phenol and cresol could be used instead it would be better.

[3] *Third Report—Cattle Plague Commission.* Carbolic acid can be distinguished from creosote by its solubility in glycerine (Morson).

insoluble, but if the amount of carbolic acid be increased, some remains undissolved.

"To apply the tests—1. Put a teaspoonful of the carbolic acid in a bottle, pour on it half a pint of warm water, and shake the bottle at intervals for half an hour, when the amount of oily residue will show the impurity; or dissolve one part of caustic soda in 10 parts of warm water, and shake it up with 5 parts of the carbolic acid. As before, the residue will show the amount of impurity.

"These tests will show whether tar oils have been used as adulterants, but to ascertain whether the liquid consists of a mere solution of carbolic acid in water or alkali, or whether it contains sulpho-carbolic or sulpho-cresylic acids, another test must be used based on the solubility of these, and the insolubility of carbolic acid, in a small quantity of water. In this case proceed as follows:—2. Put a wine-glassful of the liquid to be tested in a bottle, and pour on it half a pint of warm water. If the greater part dissolves, it is an adulterated article. Test the liquid in the bottle with litmus paper: if strongly acid, it will show the probable presence of sulpho-acids; whilst if alkaline, it will show that caustic soda has been probably used as a solvent."

If the quantity of carbolic acid has to be estimated from a liquid, it must be distilled at a given temperature. Carbolic acid boils at 184° C. (=363° Fahr.), cresol at 203° C. (=397°·4 Fahr.).

In using the liquid acid, 1 part is mixed with 50 or 100 of water, according to the strength of the acid, and thrown down drains or into cesspools, or sprinkled with a watering-can over dung-heaps.

(*c*) *Powders.*—The two principal carbolic acid powders are M'Dougall's and Calvert's, but there are several others in the market known under various names.

M'Dougall's and Calvert's powders are widely different in composition.

The former is strongly alkaline from lime, and makes the sewage alkaline. It consists of about 33 per cent. of carbolate of lime and 59 per cent. of sulphite of magnesia, the rest being water.

Calvert's powder is carbolic acid, about 20 to 30 per cent., mixed with alumina from alum works, and some silica.

The quantity of these preparations which must be used depends on the degree and duration of deodorisation wished for. For the daily solid excreta (4 ounces) of an adult at least from 30 to 70 grains of the crystallised acid, 60 drops of the strong liquid (90 per cent. of acid), or a $\frac{1}{2}$ ounce of the dilute carbolic acid, sold at 1s. per pint, are necessary, if the sewage is to be kept in an unaltered state for 10 to 20 days, but a smaller amount is sufficient for 2 or 3 days.[1] Dr Sansom, who does not rate the effect of carbolic acid so highly as a deodorant, also finds that much larger quantities must be used than is usually stated.[2] Half an ounce of either Calvert's or M'Dougall's powder for 4 ounces of sewage has a preservative effect for 18 to 20 days; $\frac{1}{4}$ ounce or less is effectual for 3 or 4 days, but if the stools contain urine much more is necessary.[3] Winter Blyth found phenol and

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[1] See Dr Parkes' experiments in the *Army Medical Department Report*, vol. viii. p. 318.

[2] *Op. cit.*, p. 203.

[3] Dr John Day (of Geelong) published a paper in the *Australian Medical Journal* (June 1874), on the comparative value as disinfectants of carbolic acid and mineral oils, such as gasolene and kerosene. He prefers gasolene, and finds it may be used for papered walls, furniture, clothing, and flooring. It must be used with caution near lights, as it is very inflammable. Dr Day attributes its action to its strong oxidising properties; paper brushed over with it gave the reaction of peroxide of hydrogen after more than a year.

cresol about equal in power, but their efficacy was greatly enhanced when mixed with caustic lime.

Smaller quantities can, however, be used, if diminution but not entire removal of smell and putrefaction is desired. Quicklime 5 parts, and carbolic acid 1 part, make a good deodorising mixture. If hydrochloric acid is added, and then water, the lime is deposited, and the carbolic acid floats on the surface, and its amount can be determined.

16. *The Süvern Deodorant.*—The water flowing from sugar factories has long been a source of annoyance and ill-health; it contains quantities of vegetable organisms (*Oscillaria alba* or *Beggiatoa*), which act like ferments, and rapidly decompose the sulphates in the water, and liberate hydrogen sulphide. Herr Süvern, to remedy this, proposed a preparation of coal-tar thus prepared:[1]—A bushel and a half of good quicklime are put in a cask and slaked; it is well stirred, and 10 ℔ of coal-tar are thoroughly mixed with it, so that the coal-tar may be thoroughly divided. Fifteen pounds of magnesium chloride dissolved in hot water are then thoroughly mixed with the mass, and then additional hot water is added, enough to make a mass of just sufficient liquidity to drop slowly from a stick inserted in it and then pulled out. The magnesium chloride forms deliquescent calcium chloride, magnesia being liberated, and it is found that this prevents the caking of the deodorant and the adherence to pipes. This deodorant has come into considerable use for cesspools, drains, &c. The Müller-Schurr deodoriser has been already noticed.

17. Dr F. T. Bond (of Gloucester) introduced some years ago a new deodorant in the form of powder and liquid, consisting essentially of metallic salts, alum, and *terebene* (a hydrocarbon derived from turpentine by treatment with sulphuric acid). Terebene has a pleasant odour, and so far is superior to carbolic acid; its deodorising powers are very considerable, and Winter Blyth found that in a 20 per cent. solution the colonies were reduced to a minimum. The preparations in the form of powder are various, the chief being *ferralum* and *cupralum*, the latter being most frequently employed. It consists of copper sulphate, aluminum sulphate, a little potassium dichromate, and terebene. It is a very powerful deodorant, counteracting ammonia and hydrogen sulphide, and at least masking fæcal odour as much as carbolic acid. Some objections were formerly made to it on account of a tendency to deliquescence, due to the presenee of sodium chloride. This has now been remedied, and the preparation keeps well.

The substance advertised as *Sanitas* is a hydrocarbon derived from turpentine acted upon by steam. It has the advantage of being easily miscible with water, but it is not very powerful.

18. The remarkable power shown by *salicylic acid* in arresting fermentation, and its value in the antiseptic treatment of wounds, would seem to indicate it as a good agent, but it is at present too expensive for use on a large scale.

General Conclusion.—It must be remembered that deodorisation is only possible within certain limits, and that in a number of cases only partial results can be obtained, unless very large quantities[2] of the deodorant are

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[1] Trautman, *Die Zersetzungsgase*, 1869, p. 35.

[2] In experimenting at Netley with the very offensive infusion of linseed, it was found almost impossible to get rid of odour without using very large quantities of the deodorants.

For further information on the subject of sewage deodorants, see the *Reports of the Royal Commission on Metropolitan Sewage Discharge*, partieularly vol. ii. See also *Digest of Facts relating to the Deodorisation and Utilisation of Sewage*, by Professor W. H. Corfield and Dr L. Parkes, 3rd edition, 1887.

used. The most effectual appear to be the terebene preparations, especially the cupralum, and carbolic acid and its preparations. Of these the cupralum has the advantage of destroying hydrogen sulphide and neutralising ammonia, which are only masked by the others. Chloride of lime and chloride of soda are also powerful, but have themselves a sickly odour, very disagreeable to many persons. The Süvern deodorant is probably the next best, and after that the ferric chloride ($FeCl_3$).

CHAPTER XVIII.

ON THE PREVENTION OF SOME IMPORTANT AND COMMON DISEASES.

THERE are two modes by which we may attempt to prevent the occurrence of disease.

1. By conforming with the general rules of hygiene, by which the body and mind are brought into a state of more vigorous health. The importance of this as providing a means of resisting disease has not always been sufficiently recognised. But there seems little doubt that in many epidemics this has been quite as important a factor as the introduction of disease poison itself.[1]

2. By investigating and removing the causes of the diseases which we find actually in operation. This part of the inquiry is in fact a necessary supplement to the other, though in proportion to the observance of the general rules of hygiene, the causes of disease will be gradually removed. At present, however, we have to deal with the facts before us, viz., that there are a great number of diseases actually existent which must form the subject of investigation. We proceed in this case from the particular to the general, whereas, in the first mode, we deduce general rules which have to be applied to individual instances.

Hygiene is in this direction an application of etiology, and etiology is the philosophy of medicine; while in its turn the very foundation and basis of etiology is an accurate diagnosis of disease. Unless diseases are completely identified, all inquiry into causes is hopeless. Let us remember, for example, what utter confusion prevailed in our opinions as to causes and preventive measures at the time when typhus and enteric fevers were considered identical, or when paroxysmal fever and the true yellow fever or vomito were thought to own a common cause. Any useful rules of prevention were simply impossible—as impossible as at present in many of the diseases of nutrition, which, in the proper sense of the word, are yet undiagnosed.

The advance of diagnosis has of late years been owing not merely to improved methods of observation, but to the more complete recognition of the great principle of the invariableness of causation. The sequence of phenomena in the diseased body proceeds with the same regularity and constancy as in astronomy or chemistry. Like causes always produce like effects. To suppose that from the same cause should proceed a sequence of phenomena so utterly distinct as those of typhus and enteric fever, now seems incredible; yet with a full, or at any rate a sufficient knowledge of the phenomena, it was at one time almost universally believed that these two perfectly distinct diseases owned a common origin. At the present moment, the superficial resemblance between gout and rheumatism causes them to be put together in almost all systems of nosology, although, with the exception of the joints being affected, the diseases have almost nothing in common.

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[1] See Creighton's *Unconscious Memory in Disease*, London, Lewis, 1886.

In proportion as this great principle is still more constantly applied, and as our means of diagnosis advance, and consequently, causes are more satisfactorily investigated, methods of prevention will become obvious and precise. At present they are very far from being so. In many cases they are founded on very imperfect observation; and very frequently all that can be done is to apply general sanitary rules, without attempting to determine what are the special preventive measures which each disease requires.

It is not necessary, however, that we should wait until the causation of any disease is perfectly understood. We must act, as in so many other affairs, on probability; and endeavour to remove those conditions which, in the present state of our knowledge, seem to be the most likely causes of the disease. It may be that, in some cases, we may be attacking only subsidiary or minor causes, and may overlook others equally or more important. In some cases, indeed, we may overlook entirely the effective causes, and may be fighting with shadows. Still, even from mistakes progress often arises,—indeed, the difficult path of human knowledge is perhaps always through error.

The term cause is applied by logicians to any antecedent which has a share in producing a certain sequence; and it is well known that in many diseases two sets of causes are in operation—one external and one internal to the body (exciting and predisposing). The investigation of the internal causes, which in some cases are necessary to the action of the external causes, is equally curious and intricate as that of the external causes, and in some respects it is even more obscure; but measures of prevention must deal with them as well as with the external causes.

In this chapter we can, of course, only venture to enumerate very briefly, and without discussion, what seem to be the best rules of prevention for the principal diseases of soldiers. To enter on the great subject of the prevention of disease generally, and to discuss all the complicated questions connected with causation, would demand a volume.

SECTION I.

THE SPECIFIC DISEASES.

Paroxysmal Fevers.[1]

External Cause.—This was presumed to be putrescent, or, at any rate, decomposing vegetable matter derived from a moist and putrescent soil, which was carried into the body by the medium of water or of air. But the later views of Klebs and Tommasi-Crudeli attribute it to a low organism of the nature of *Bacillus*, to which they have given the name *Bacillus malariæ*, propagated in the presence of decaying vegetable matter. This view, however, has not yet been completely corroborated.

If the ingestion is by water, a fresh source must be obtained. Well water is generally safe, but not always. Rain water may be unsafe, if the tanks are not clean.[2] If a fresh source cannot be obtained, boiling, filtration, and alum, as well as infusion with tea or coffee, appear to be the best preventive measures.[3]

If the introduction be by air, and if the locality cannot be left, the most

[1] See Mr North's Lectures, *Brit. Med. Journal*, 1887.

[2] For instance of propagation by so-called rain-water, see cases at Tilbury Fort, noted at page 46.

[3] Dr Blanc and Mr Prideaux preserved themselves from intermittent fever, in a march in Abyssinia, by always using water in the form of tea or coffee.

approved plan is elevation to at least 500 feet above *the source of the poison* in temperate climates; and 1000 to 1500 feet in the tropics, or higher still, if possible.[1] If this plan cannot be adopted, two points must be aimed at—viz., to obviate local, and to avoid drifting malaria. Thorough subsoil draining; filling up moist ground when practicable; paving or covering the ground with herbage kept closely cut, are the best plans for the first point. For the second, belts of trees, even walls can be interposed; or houses can be so built as not to present openings towards the side of the malarious currents.

The houses themselves should be raised above the ground on arches; or, if wooden, on piles. Upper floors only should be occupied. The early morning air, for three hours after sunrise, should be avoided, and, next to this, night air.

Internal Causes.—The conformation, or structural condition, which permits the external cause to act, is evidently not equal in different individuals, or in different races; but we are quite ignorant of its nature. It is not removed by attacks of the disease; but, on the contrary, after repeated attacks of ague, a peculiar condition is produced, in which the disease can be brought on by causes, such as cold or dietetic errors, which could never have caused it in the first instance.[2] The internal predisposition is greatly heightened by poor feeding, anæmia, and probably by scurvy.

To remove the internal causes our only means at present are the administration of antiperiodics, especially quinine, and good and generous living, with iron medicines. The use of flannel next the skin, and of warm clothing generally; warm coffee, and a good meal before the time of exposure to the malaria, and perhaps moderate smoking (?), are the other chief measures. Wine in moderation is part of a generous diet; but spirits are useless, and probably hurtful, unless given considerably diluted.

Yellow Fever.

External Cause.—During late years the progress of inquiry has entirely disconnected true yellow fever from malaria, though yellowness of the skin is a symptom of some malarious fevers. Yellow fever is a disease of cities, and of parts of cities, being often singularly localised, like cholera. In the West Indies it has repeatedly attacked a barrack (at Bermuda, Trinidad, Barbadoes, Jamaica), while no other place in the whole island was affected. In the same way (at Lisbon, Cadiz, and many other places) it has attacked only one section of a town, and, occasionally, like cholera, only one side of a street. In the West Indies it has repeatedly commenced in the same part of a barrack. In all these points, and in its frequent occurrence in non-malarious places, in the exemption of highly malarious places, in its want of relation to moisture in the atmosphere, and its as evident connection with putrefying fæcal and other animal matters, its cause differs entirely from malaria.[3]

If these points were not sufficient, the fact that the agent or poison which causes yellow fever is portable, can be carried and introduced among a com-

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[1] It must be understood that these heights are assumed to be *above* a marsh. They will not secure from malaria from marshes, if situated at that or a much greater height. A marsh at Erzeroum is 6000 feet above sea-level; one at Puebla, in New Mexico, is 5000 feet; both cause fevers.

[2] See Creighton, *op. cit.*

[3] The belief in the malarious origin of yellow fever, so long and tenaciously held by many American physicians, seems to be losing ground. (See paper by Dr Perry, read before the American Health Association, *The Daily Picayune*, Nov. 23, 1873.)

munity,[1] and is increased in the bodies of those whom it attacks, indicates that the two agencies of yellow fever and paroxysmal fevers are entirely distinct.[2]

That great point being considered settled, the inquiry into the conditions of the spread of yellow fever becomes easier. The points to seize are its frequent and regular localisation and its transportation. The localisation at once disconnects it from any general atmospheric wave of poison; it is no doubt greatly influenced by temperature, and is worse when the temperature is above 70° Fahr. (21° C.). Though it will continue to spread in a colder air than was formerly supposed, it does not spread rapidly, and appears to die out; but even temperature does not cause it to become general in a place.

The localising causes are evidently (cases of Lisbon, Gibraltar, West Indies, &c.) connected with accumulation of excreta round dwellings, and overcrowding. Of the former there are abundant instances, and it is now coming out more and more clearly that, to use a convenient phrase, yellow fever, like cholera and typhoid fever, is a fæcal disease. And here we find the explanation of its localisation in the West Indian barracks in the olden time. Round every barrack there were cesspits, often open to sun and air. Every evacuation of healthy and sick men was thrown into perhaps the same places. Grant that yellow fever was somehow or other introduced, and let us assume (what is highly probable) that the vomited and fæcal matters spread the disease, and it is evident why, in St James' Barracks at Trinidad, or St Ann's Barracks at Barbadoes, men were dying by dozens, while at a little distance there was no disease. The prevalence on board ship is as easily explained. Granted that yellow fever is once imported into the ship, then the conditions of spread are probably as favourable as in the most crowded city; planks and cots get impregnated with the discharges, which may even find their way into the hold and bilge. No one who knows how difficult it is to help such impregnation in the best hospitals on shore, and who remembers the imperfect arrangements on board ship for sickness, will doubt this. Then, in many ships, indeed in almost all, in unequal degrees, ventilation is most imperfect, and the air is never cleansed.

Overcrowding, and what is equivalent, defective ventilation, is another great auxiliary; and Bone[3] relates several striking instances.[4]

The question of the origin of yellow fever is one which cannot be considered in this volume, and at present no preventive rules of importance can be drawn from the discussion. Audouard's view, however, may be cited as

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[1] Cases of the Bann, Eclair, Icarus, and several others. The remarkable introduction of yellow fever from Havannah into St Nazaire, in France (near Brest), is most striking, and cannot be explained away. It spread both from the ship, and, in one instance, from persons. (See Aitken's *Medicine*, 7th edit., 1880; and Report on Hygiene for 1862, in the *Army Medical Report*, by Dr Parkes.) The introduction into Rio in 1849, and into Monte Video, are still more striking cases of importation; and a case very similar to that of St Nazaire occurred some years ago at Swansea. (See *Report* (by Dr Buchanan) *to the Medical Officer of the Privy Council*, 1866.)

[2] As more care is taken, the symptoms of the two diseases also are found to be diagnostic, and if it were not for the constant use of the unhappy term "remittent," the confusion would not have so long prevailed.

An interesting instance of good diagnosis was made by the French at Vera Cruz in 1861. In the spring the vomito prevailed, and then disappeared. Some months afterwards, cases of a disease occurred so like yellow fever that they were at first taken to be that disease, but on a closer examination they were found to be clearly paroxysmal, and to yield to quinine.—*Rec. de Mem. de Méd. Milit.*, 1863.

[3] *Yellow Fever*, by G. F. Bone, Assist.-Surg. to the Forces.

[4] For example, in the same barrack, the windward rooms have been quite healthy, and the leeward rooms attacked. Men in the latter have ceased to have cases of the disease when moved to the former locality. (See a good case in Bone, *op. cit.*, p. 13.)

having much to commend it, viz., that it is due to the dysenteric evacuations of slaves in the slave-trade times. The known immunity of the black races to the disease seems to corroborate this.

The chief preventive measures for the external cause are these:—

1. The portability being proved, the greatest care should be taken to prevent introduction, either by sick men or by men who have left an infected ship. The case of the "Anne Marie"[1] has made it quite uncertain what period of time should have elapsed before an infected ship can be considered safe; in fact, it probably cannot be safe until the cargo has been discharged and the ship thoroughly cleansed. Still, it appears that if men leaving an affected place or ship pass into places well ventilated and in fair sanitary condition, they seldom carry the disease; in other words, the disease is seldom portable by men, but it will occur. It appears necessary, also, to consider that the incubative period is longer than usually supposed, probably often fourteen or sixteen days. In the case of a ship, it seems desirable not to consider danger over until at least twenty days have elapsed since the cure or death of the last case, and even at that time to thoroughly fumigate the ship with chlorine and nitrous acid before the cargo is touched. Men working on board such a ship should work by relays, so as not to be more than an hour at a time in the hold.[2]

In case men sick with yellow fever must be received into a barrack or hospital, they should be isolated, placed in the best-ventilated rooms at the top of the house, if possible, or, better still, in separate houses, and all discharges mixed with zinc sulphate, zinc chloride, or mercuric chloride, and separately disposed of, and not allowed to pass into any closet or latrine, or, better still, burned.

2. The introduction by drinking water not being disproved, care should be taken that the possibility of this mode of introduction be not overlooked. The provision of pure drinking water is also a part of general hygiene.

3. Perfect sewerage and ventilation of any station would probably in great measure preserve from yellow fever,[3] but, in addition, in the yellow fever zone, elevation is said to have a very great effect, though the confusion between malarious fevers and the vomito renders the evidence on this point less certain, and its introduction into Newcastle, in Jamaica (4200 feet), and its frequent occurrence at Xalapa (4330 feet), as well as its prevalence on high points of the Andes (9000 feet) (A. Smith), show that the effect of mere elevation has been overrated. Still, as a matter of precaution, stations in all yellow fever districts should be on elevations above 2000, and if possible 3000 feet.

4. If an outbreak of yellow fever occur in a barrack, it is impossible then to attempt any cleansing of sewers; the only plan is to evacuate the barracks. This has been done many times in the West Indies with the best effects. As a preventive measure, also, evacuation of the barracks, and encampment at some little distance, is a most useful plan. Before the barrack is reoccupied, every possible means should be taken to cleanse it; sewers should be thoroughly flushed; walls scraped, limewashed, and fumigated with nitrous acid. If a barrack cannot be altogether abandoned, the

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[1] See Aitken's *Medicine*, and Report on Hygiene in the *Army Medical Report* for 1862.

[2] Dr Perry (*op. cit.*) considers quarantine useless, and advises a most rigorous system of disinfection. He cites eight instances of the introduction of yellow fever through a strict quarantine,—seven to New Orleans and one to Pensacola.

[3] See the case of the city of Memphis, in the valley of the Mississippi; see Col. Waring's paper in *Trans. Sanitary Institute of Great Britain*, vol. ii. p. 291.

ground floors should be disused. There are several instances in which persons living in the lowest story have been attacked, while those above have escaped.

5. Where fumigation is employed, nitrous acid seems to be, as far as we know, the best disinfectant for this disease.

6. If it appears on board ship, take the same precautions with regard to evacuations, bedding, &c. Treat all patients in the open air on deck, if the weather permit; run the ship for a colder latitude; land all the sick as soon as possible, and cleanse and fumigate the ship.

Internal Cause.—Recent arrival in a hot country has been usually assigned as a cause, but the confusion between true yellow fever, severe febricula (ardent fever or *causus*) and malarious fevers renders it uncertain how far this cause operates.[1] Still, as a matter of precaution, the present plan of three or four years' Mediterranean service before passing to the West Indies seems desirable, although this has been questioned by some experienced officers. Different races possess the peculiar habit which allows the external cause to act in very different degrees; this is marked in the cases of negroes and mulattoes as compared with white men, but even in the European nations it has been supposed that the northern are more subject than the southern nations. Of the sexes, women are said to be less liable than men.

This predisposition is increased by fatigue,[2] and, it is said, especially when combined with exposure to the sun; by drinking, and by improper food of any kind which lowers the tone of the body.

No prophylactic medicine is known; quinine is quite useless.

Little, therefore, can be done to avert the internal causes, except care in not undergoing great fatigue, temperance, and proper food.

Dengue.

This disease, which has attracted much attention of late years, appears to bear some relation to yellow fever, not in its pathological characters, but in the time of its appearance and geographical distribution. It has, however, prevailed in Asia, where yellow fever has hitherto been unknown. In Egypt (according to Vauvray) it is seen at the time of the date-harvest, and is known as "date-fever." In other parts of the world it has been attributed to vegetable emanations. Although its symptoms are those of blood-poisoning, it may be doubted if this is due to vegetable emanations only. Dr J. Christie[3] thinks that the Dengue of the Eastern and the Dandy fever of the Western Hemispheres are varieties of the same disease, produced in the one case by the virus of yellow fever, and in the other by that of cholera, modified by local conditions of an insanitary kind, chiefly decomposition of bodies improperly interred. He suggests general hygienic measures, and especially improved methods of burial, as the best preventives.

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[1] In the old times in Jamaica it was, however, always noticed that the worst attacks occurred in regiments during the first twenty-four, and especially the first twelve months. In thirteen epidemics in different regiments, four occurred in less than six months after landing, seven in less than twelve months, and two in less than twenty-four months. But it has been stated that residence in one place, though it may secure against the yellow fever of that, does not protect against the disease in another locality. It is much to be wished that all these assertions which abound in books should be tested by figures. That is the only way of coming to a decision.

[2] Arnold, *Bilious Remittent Fever*, 1840, p. 32.

[3] *Transactions of the International Medical Congress*, 1882, vol. iv. p. 636.

Cholera.[1]

External Cause.—We have no certain clue to the origin of cholera,[2] and in some respects the propagation of the disease is very enigmatical. The way, for example, in which the disease has spread over vast regions, and has then entirely disappeared,[3] and the mode in which it seems to develop and decline in a locality, in a sort of regular order and at certain seasons, are facts which we can only imperfectly explain.

But as far as preventive measures are concerned, the researches of late years seem to have given us indications on which we are bound to act, though they are based only on a partial knowledge of the laws of spread of this poison.

These indications are—

1. The portability of the disease, *i.e.*, the carriage of cholera from one place to another by persons ill with the disease, both in the earliest stage (the so-called premonitory diarrhœa) and the later period, and in convalescence.[4] The carriage by healthy persons coming from infected districts is not so certain; but there is some evidence.[5] It is clear this last point is a most important one, in which it is desirable to have more complete evidence. The occasional carriage by soiled clothes, though not on the whole common, has also evidence in its favour. All these points were affirmed by the Vienna Conference of 1874. Even Pettenkofer admitted that man is the carrier of the disease germ, although the *locality* may be the means of rendering it potent. On the other hand, Dr J. M. Cuningham[6] makes a *tabula rasa* of everything, denies the transportability of the disease either by persons or by water, and says there is a mysterious factor still to be sought for. His evidence, however, cannot be considered as conclusive.

Whatever may be the final opinion on all these points, we are bound to act as if they were perfectly ascertained. It is usually impossible to have rigid quarantines; for nothing short of absolute non-communication would be useful, and this is impossible except in exceptional cases. For persons very slightly ill, or who have the disease in them but are not yet apparently ill, or possibly who are not and will not be ill at all, can give the disease, and therefore a selection of dangerous persons cannot be made.[7] Then, as the incubative stage can certainly last for ten or twelve days, and there are some good cases on record where it has lasted for more than twenty, it is clear that quarantine, unless enforced for at least the last period of time,

[1] For Special Instructions, see Appendix 5, *Medical Regulations*, 1885.

[2] The researches of Lewis and D. D. Cunningham in India, and of Eberth,[1] of Zürich, showed that no specific germ had then been discovered, and disproved the fungoid and other origins proposed by Hallier, &c. The more recent observations of Koch, &c., have been already referred to.

[3] There is, of course, no doubt that the common autumnal cholera, however much it may resemble superficially the Indian cholera, is quite a separate disease, although some recent observers appear inclined to hold a different opinion.

[4] With respect to convalescence, the only evidence is apparently that given by Volz, quoted by Hirsch, *Jahresb. für ges. Med.*, 1868, Band ii. p. 221.

[5] Especially in the Mauritius outbreaks, where parties of coolies coming from places where cholera prevailed, but being themselves healthy, gave cholera to other parties of coolies who had arrived from India, and had no disease among them. Dr Leith Adams (*Army Medical Report*, vol. vi. p. 348), in his excellent Report on Cholera in Malta, states:—"There are many pointed facts to show that cholera may be introduced and communicated to susceptible persons by healthy individuals from infected districts."

[6] *Ninth Annual Report of the Sanitary Commissioner with the Government of India.*

[7] Pettenkofer believes that man is the carrier of the poison, whether he be sick or well, and that the sick man is not a danger because he is actually ill of cholera, but because he comes from the infected locality.

[1] *Zur Kenntniss der Bacteritischen Mykosen*, Von J. C. Eberth, 1873.

may be useless. The constant evasions also of the most strict cordon render such plans always useless. An island, or an inland village, far removed from commerce, and capable for a time of doing without it, may, perhaps, practise quarantine and preserve itself; but, in other circumstances, both theory and actual experience show that quarantine fails.[1] M. Fauvel[2] believed that the quarantine measures adopted in the Red Sea had been instrumental in preventing the spread of cholera to Europe on three separate occasions, namely, 1872, 1877, and 1881. The futility of quarantine was, however, distinctly affirmed by the Committee appointed by the Secretary of State for India to consider the Report of MM. Klein and Heneage Gibbes in 1885.

This difficulty, however, of carrying out efficient isolation is no argument against taking every precaution against communication, and keeping a strict watch and control over every possible channel of introduction. In this way, by isolation of the individual, or of bodies of men, as far as possible, and by looking out for and dealing with the earliest case, an outbreak may perhaps be checked, especially by discovering the diarrhœal attacks, and by using disinfectants both to the discharges and to linen.[3] In the case of troops coming from infected districts they should be kept in separate buildings for twenty days, and ordered to use only the latrines attached to them, in which disinfectants should be freely used.

2. The introduction of the disease into any place by persons is considered by most observers to be connected with the choleraic discharges, either when newly passed, or, according to some, when decomposing. The reasons for this are briefly these: the portability being certain, the thing carried is more likely to be in the discharges from the stomach and bowels than from the skin or breath (the urine is out of the question), and for these reasons:— Water can communicate the disease, and this could only be by contamination with the discharges; water contaminated by discharges has actually given the disease, as in Dr Macnamara's cases; in some cases a singularly local origin is proved, and this is nearly always a latrine, sewer, or receptacle of discharges, or a soil impregnated with choleraic evacuations; soiled linen has sometimes given it, and this is far more likely to be from discharges than from the perspiration; animals (white mice and rabbits) have had cholera produced in them from feeding on the dried discharges. Finally, in the history of the portability of cholera, there are many instances in which, while there has been decided introduction by a diseased person into a place, there has been no immediate relation between that person and the next case; in other words, the cause must be completely detachable from the first case, and must be able to act at a distance from

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[1] When circumstances are favourable (as respects trade and intercourse), however, good quarantine may be successful even on the mainland. This was shown in Algeria in 1861. See Dr Dukerley's *Notice sur les Measures de Préservation prises à Batna (Algérie) pendant le Choléra de* 1867, Paris, 1868, for a very interesting account of those successful measures of which strict isolation and constant hygienic measures were the principal. So also in America, Dr Woodward states (*Circular on Cholera*, No. 5 Surgeon-General's Office, Washington, 1867) that "the general tenor of army experience is strongly in favour of quarantine." Quarantine on land was condemned by the Vienna Conference, but recommended on the Red Sea and the Caspian. In Europe, however, only rigorous inspection was recommended, with various rules for preventing spread as much as possible.

[2] *Revue d'Hygiène*, vol. iv. 1882, p. 754.

[3] The Indian Government are now cautiously attempting to limit the spread of cholera by superintending and controlling the pilgrimages, which are so common a cause of the spread of cholera in India. The Report of the Cholera Committee (Inspector-General Mackenzie, Colonel Silva, and Dr Ranking) to the Madras Government, published at Madras in 1868, gives a great deal of important evidence on this point, and in addition lays down excellent rules for the management of pilgrimages.

his body; it is therefore far more probable that the discharges are this carrying agency, than that any effluvia should pass off from the lungs and skin which could spread to a great distance.

Enough has been said to show that the discharges must receive the most careful attention. Every discharge ought to be disinfected with strong substances liberally used; the best are carbolic acid (in large quantity), perchloride of iron, chloride of zinc, chloride of lime, corrosive sublimate (used very diluted and with caution), cupralum, or, if none of these are at hand, good quicklime. Although the results of disinfection of the discharges have not hitherto been encouraging, the plan has seldom been completely tried. All latrines should be disinfected, sewers flushed, carbolic acid poured down them, and every means taken to keep them ventilated.

What should be done with the disinfected discharges? Should they be allowed to pass into sewers, or buried in the ground? They must in some way be got rid of. Sewers certainly afford an easy mode of disposing of them; and as the discharges are mixed with much water, and are rapidly swept away in them, and as the temperature of the sewers is low, and decomposition is delayed, it is quite possible that sewers may be a means of freeing a town from choleraic discharges more easily than any other plan. And it appears to be a fact that in the well-sewered towns in England the cholera of 1865 and 1866 never attained any wide spread. In Munich, in the cholera epidemic of 1873, the well-sewered parts of the town had only one-half the sickness and mortality of the others, which were either imperfectly drained or not at all.[1] In large towns, also, there are no other means of disposing of the discharges. But may not sewers be a means of dissemination,[2] and thus, as in some outbreaks of enteric fever, be a source of danger? And again, when sewerage is poured over land, as it will be soon throughout all England, are we quite sure that no choleraic effluvia will pass off, or that the choleraic particles passing into the ground may not develop there, as Pettenkofer supposes is the case? There are no facts to enable us to decide, but the possibility of mischief arising in this way should, at any rate, make us still more urgent in the use of disinfectants to all discharges.

Again, as to disposal in the earth, if Pettenkofer is correct, that a loose moist earth is the place where the supposed germ of cholera acquires its power, the last place we should put a choleraic discharge would be the earth; still, as there is much to be said against Pettenkofer's views, and as in small towns and villages there is only the alternative of allowing the discharges to pass into cesspools or streams, or to be disposed of in the earth, it would seem to be the safest course to deeply bury all disinfected discharges, care being taken to place them at a distance from houses and from sources of water supply. Another excellent plan would be to mix them with sawdust and burn them.

That linen and bedding should be carefully disinfected needs no argument; compressed steam is to be preferred. In some English towns all cholera clothing has been burnt, but whether this measure is necessary or not is uncertain. But thorough steeping and boiling before washing is essential, as washerwomen have certainly suffered in many cases.

3. The introduction of the agent by the medium of the air is generally admitted, on the plea that cases occur in which any other mode of entrance is

[1] Soyka, *Deutsche Viertlj. f. öff. Ges.*, Band xiv. Heft 1, p. 54, 1882.

[2] That these may be so, in a particular way, was shown to be probable in Dr Parkes' Report on Cholera in Southampton (*Sixth Report of the Medical Officer to the Privy Council*, p. 251); but still there is very little evidence on this point.

impossible. It is also held by some that, existing in the air, it can be carried for great distances by winds; and some observers indeed believe this to be its usual mode of transit, though this opinion appears opposed to all we know of its spread.

Without attempting to decide the point or to state the limits of the transmission, it is a matter of prudence to act as if the winds did carry the poison. The Indian rule is to march at right angles to the wind, and never against it or with it if it can be avoided. The spreading by the winds in India has been usually ascribed to the custom of throwing all the cholera evacuations on the ground; there they get dried, and then are lifted by the wind and driven to other parts. This seems probable, but no decided proof has been given; and an argument against it may be raised on the difficulty of accounting for the immunity of adjacent places if such transmission were common. So also the use of aërial disinfectants in cholera is rendered imperative by the chance that the cause may be in the air. The use of sulphur fires has been advocated and tried in India, apparently with good effect (Crerar and Tuson). The Vienna Conference affirmed transmission by the air, but only to a short distance, and never faster than man travels. They also recognised the great safeguard afforded by deserts, as the disease has never been known to be imported into Egypt or Syria across the desert by caravans from Mecca.[1]

4. The occasional, perhaps frequent, introduction by water seems certain. It was unanimously affirmed at the Vienna Conference, even by Pettenkofer, who has, however, since abandoned this view. It is a good plan always to change the source of supply, to use rain-water if no other fresh source is procurable; and in every case to boil and filter, and to use also potassium permanganate.[2] It remains yet uncertain whether a water which gives cholera is always chemically impure, or whether the choleraic matter may be in so small a quantity as to be absolutely indetectable. In the two cases examined by Dr Parkes, in which the water was the cause, it was highly impure. In India it is now ordered that all the water should be boiled.[3]

5. The introduction by food has been noted in some cases (although the Vienna Conference decided, by 11 to 7, that present facts do not warrant a decision). Every article of food, solid and liquid, should therefore be passed in review, and the cooking arrangements gone over step by step.[4]

6. The localisation of cholera is a marked feature in its history.[5] It is often as marked as in yellow fever, and may be confined to a very small area. At other times, in India, the "tainted district" may be of some extent. From this fact of localisation arises the important rule of always leaving the

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[1] On this point the history of Chili is interesting, as cholera has never reached it. It is separated on the north from Peru by the desert of Attacama, and from the Argentine Confederation on the east by the Andes range, to which circumstances its immunity hitherto from epidemic diseases has been ascribed by the inhabitants. More recently, however, it is stated to have appeared there.

[2] In the very able *Report on Epidemic Cholera in the United States Army* (Circular No. 5, War Department; Surgeon-General's Office, Washington) is what appears to be a good instance of the effect of changing the supply. At New Orleans rain, and in some cases distilled, water was supplied instead of river water, with the apparent effect of checking the spread (p. xvii.); see also the cases of Utrecht and Rotterdam, as reported by Buys-Ballot.

[3] G. O. C. C., No. 192, clause 53. Förster, of Breslau (*Die Verbreitung der Cholera durch die Brunnen*, 1873), urges two recommendations which he thinks will prevent cholera in the future—1st, Lead to every town, even if at great cost, abundant and pure water, as indeed was done, he says, much better 2000 years ago than now. 2nd, Protect the ground from contamination in any way from excrement, and banish all cesspits. The ground must be absolutely pure, and this can only be if all fæcal matter is removed to a distance.

[4] See Dr Fairweather's Delhi case in the *Sanitary Report of the Punjab* for 1871; also given in Report on Hygiene, in the *Army Medical Report*, vol. xiii. (1873).

[5] Surgeon P. Cullen (*Indian Medical Gazette*, 1st July 1873) notices a very singular case of localisation at Etarsi.

locality when practicable, and in a large town of clearing out the house where cholera has happened. In India the present rule is to march the men out and encamp in a healthy spot at some little distance, changing the encamping ground from time to time. On the whole, this has acted well, and should be adhered to, though occasionally it has failed, generally, however, it would seem, from error in choice of locality. The men should be tented; the tents should be well ventilated, and often struck and repitched; an elevated spot should be chosen, and damp and low soils and river banks avoided. Orders lay down with precision the exact steps to be taken by a regiment when cholera threatens.[1] The rule of marching out must, of course, be subject to some exceptions. It has been advised that it should not be done in the rainy season in India. This must depend on the locality. It appears sometimes to have answered well, even in heavy rains; but in other cases the rains may be too heavy. No absolute rule can be laid down; but the circumstances which are allowed to set aside the grand rule of evacuation of a tainted place should be unequivocal.

In connection with change of locality, the opinions of Pettenkofer should be borne in mind. Pettenkofer believes that, of all conditions, the effect of soil is the most important. It is necessary, then, to consider particularly the nature of the soil where the fresh camps are to be placed, and to select perfectly dry, and, if possible, pure, impermeable, uncontaminated soils, and to prevent the cholera discharges from percolating through the ground.

7. Men sick from cholera are also best treated in well-ventilated tents, whenever the season admits of it. Even in cold countries, up to the end of October or the middle of November tents can be used if properly warmed. In India it should be a rule to treat every cholera patient in a tent, as far as circumstances permit it.

Internal Causes.—General feebleness of health gives no predisposition, nor is robust health a safeguard; some even have thought that the strongest men suffer most. Great fatigue, and especially if continued from day to day, greatly predisposes; of this there seems no doubt.[2] No certain influence has yet been traced to diet, although it has been supposed that a vegetable diet and alkalinity of the intestinal contents may predispose. It does not appear that insufficient diet has any great effect, though there is some slight evidence that scurvy increases the mortality, and perhaps the predisposition.[3] The strictest temperance does not preserve from attacks; but every one agrees that spirits are no protection, and that debauchery increases liability.

Of pre-existing diseases, it has been supposed that cardiac affections and pulmonary emphysema predispose; the evidence is very unsatisfactory. If

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[1] The order in India is, if a single case occur in a barrack, to vacate that part of the barrack, and to encamp the men in the cantonment. If a second case occur among the body of men thus removed, they are again moved, and the building or tent is vacated and purified. If a third case occur in this body of men within a week, they are removed to the preparatory camp.

Buildings are purified by scraping and washing walls with hot caustic limewash; boiling punkah fringes, ropes, curtains, &c., and using chloride of lime or other disinfectant. Tents are purified by being fumigated with either chlorine, nitrous acid, or sulphurous acid, and then exposed to the weather for ten days. Railway carriages, after occupation by troops carrying cholera, are purified by washing with boiling water containing in each gallon a wine-glassful of carbolic acid, and burning sulphur in the closed carriages for two hours. If troops are moved by rail, they are not to use latrines, but trenches are to be dug for them (G. O. C. C., No. 193).

[2] There are many instances of the effects of long marches. See Orton, Lorimer, and Thom, quoted in *Brit. and For. Med. Chir. Rev.*, July 1848, pp. 85-87.

[3] For some evidence as to scurvy, see Pearce and Shaw, "On the Cholera of the Jail at Calicut," *Madras Medical Journal*, July 1863.

Beale's observations be correct, post-mortem examinations often show previous affection of the villi and mucous membranes of the intestines generally; but it is very desirable there should be more proof of this.

Diarrhœa predisposes; and any causes which lead to diarrhœa, especially impure water, dietetic errors, &c., should be carefully looked after.

With regard to prophylactic measures (except in respect to proper diet, free ventilation, and pure water) nothing has been yet made out. Quinine has been recommended, and should certainly be given, especially in malarious countries, as it is a fact that the choleraic poison and malaria may act together, and even give a slight periodical character to choleraic attacks, which is never seen in non-malarious districts, and is therefore merely grafted on cholera. Peppers, spices, &c., have been used, but there is no good evidence respecting them. All diarrhœa should be immediately checked, and this is well known to be the most important point connected with the prevention of the internal causes. The universal order in India is, that any man going twice in one day to the latrine should report himself; and non-commissioned officers are usually stationed at the latrines to watch the men. The reason of this rule should be fully explained to the men. In two attacks of cholera in India, Dr Parkes found it almost impossible to get the men to report themselves properly; the slight diarrhœa of early cholera is so painless that they think nothing of it.[1] In England and Germany house-to-house visitation has been found very useful.[2]

Typhus Exanthematicus (*Spotted Typhus*).

External Cause.—An animal poison, origin unknown, but communicable from person to person, probably through the excretions of the skin and lungs floating in the air. Not known to be communicated by water or food. Its spread and its fatality are evidently connected with overcrowding and debility of body from deficient food. That it can be produced by overcrowding alone is yet uncertain.[3] The preventive measures may be thus shortly

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[1] Several points have been taken from Mr Dickinson's useful little pamphlet on the *Hygiene of Indian Cholera*, 1863.

[2] Great importance has been attached to the meteorological condition attending outbreaks of cholera; they do not appear to be very important, except in two or three cases.

1. *Temperature.*—A high temperature favours the spread by increasing the putrefaction of the stools, and by augmenting generally the impurity of the air. When cholera has prevailed at a low temperature (it has been severe at a temperature below freezing), the drinking water has possibly been the cause.

2. *Pressure* has no effect. The old observation of Prout, that the air is heavier in cholera epidemics, has never been confirmed.

3. *Moisture in Air.*—Combined with heat, this seems an accessory cause of importance, probably by aiding transmission. Moisture in the ground, combined with heat of the soil, has always been recognised as an aiding cause of great importance.

4. *Dryness of Air* seems decidedly to check it.

5. *Rain* sometimes augments, sometimes checks it. This, perhaps, depends on the amount of rain, and on whether it renders the drinking water more or less pure. A very heavy rain is a great purifier.

6. *Movement of Air.*—It is certainly worst in the stagnant atmospheres, as in the cases of all the specific poisons.

7. *Electricity* is not known to have any effect. This was particularly examined by Mr Lamont, in Munich, one of the most celebrated physical philosophers of our time, but with entirely negative results.

8. *Ozone* has no effect, either in its presence or absence (Schultze, Voltotine, De Wethe, Lamont, Strambio, Wunderlich).

[3] During the French war of 1870, although there was much crowding, wretchedness, and misery in Paris, and particularly in Metz, there was but little typhus; it was nothing like the amount in the first Napoleon's time (Grellois, *Histoire Médicale du blocus de Metz*, 1872, Chauffard, Académie de Médicine).

summed up :—Adopt isolation [1] of patients ; use the freest ventilation (5000 to 6000 cubic feet per head per hour or more) ; evolve nitrous acid and chlorine fumes in places not in actual occupation ; thoroughly fumigate with sulphurous acid, heat (to 220° Fahr.), wash, and expose to air all bedding (including mattresses) and clothes. This last point is extremely important. In fact, it may be said that, for the prevention as well as treatment of typhus, the cardinal measures are abundance of pure air and pure water. Whenever practicable, treat all typhus patients in tents, or wooden huts with badly-joined walls, not in hospitals. Fumigate tents and scrape and limewash huts, and remove earth from time to time from the floors. A number of typhus patients should never be aggregated ; they must be dispersed ; and if cases begin to spread in an hospital, clear the ward, and then, if the disease continues, the hospital itself ; then wash with chloride of lime, and then limewash or scrape walls and floors, and thoroughly fumigate with nitrous acid. It has been often shown that even exposure to weather, bad diet, and insufficient attendance are less dangerous to the patients than the aggregation of cases of typhus.

Internal Causes.—A special condition of body is necessary, as in the case of smallpox, and one attack protects to a great extent from another. The nature of the internal condition is unknown ; but general feebleness from bad diet, overwork, exhaustion, and especially the scorbutic taint, greatly increase the intensity of the disease in the individual, and perhaps aid its spread. These conditions, then, must be avoided. But the strongest and best health is no guarantee against an attack of typhus.

Bubo or Oriental Plague (Pali Plague in India).[2]

The preventive measures should be the same as in typhus, to which this disease shows great analogy. The history of the plague at Cairo (from which it has now been banished for many years simply by improving the ventilation of the city),[3] and the disappearance, after sanitary improvements, of the Pali plague in India, and its recurrence on the cessation of preventive measures, show that, like typhus, the bubo plague is easily preventible. Elevation, as in so many other specific diseases, has a considerable effect : the village of Alum Dagh, near Constantinople (1640 feet above the sea), and freely ventilated, has never been attacked ; the elevated citadel of Cairo has generally been spared ; and when Barcelona was attacked the elevated citadel also escaped.

Enteric or Typhoid Fever.

External Cause.—A poison of animal origin ; one mode of propagation is by the intestinal discharges of persons sick of the disease ; other modes of

[1] By the term isolation is meant the placing a patient in a separate building, not in another room in the same building ; in the case of smallpox, typhus, and scarlet fever this partial isolation, though sometimes successful, cannot be depended upon. If a room must be chosen in the same building, choose the top story, if a room can be there found.

[2] The Pali plague (Māhā Mārī), which was most common in Rajpootana, was evidently propagated by the filthy habits of the inhabitants (see Ranken and others), and was some years ago almost entirely got rid of by sanitary measures. Subsequently, these were neglected, and the disease returned. It has now again greatly lessened. Hirsch has pointed out that the Pali plague differs from the Egyptian plague in having a marked lung disease, and in this it resembles the black death in the fourteenth century, with which Hirsch, in fact, considers it identical.

[3] Stamm, in Pappenheim's *Beiträge*, 1862-3, p. 80. The measures adopted in Cairo were levelling some hillocks which stopped the air from blowing over the city, filling up some marshes, and adopting a better mode of burial. The peculiar sepulture customs of the Copt have even indeed been assigned as the sole cause of the origin of plague.

origin and transmission are not disproved. There is doubtless a frequent transmission of the disease by the diarrhœa of mild cases which are often not diagnosed. There is some evidence that persons considered convalescent may carry the disease,[1] but it is possible that this may have been owing to badly washed clothes. The mode of entrance into the body is both by air and water. Entrance by food (milk) has been also proved in recent years. As means of arresting the disease, isolate the patients; receive all evacuations (fæces and urine) into the vessels strictly kept for one sick person; place mercuric or zinc chloride, or ferrous sulphate, or carbolic acid, &c., in the vessels; never empty any evacuation into a closet, sewer, or cesspool; bury it several feet deep, and mix it well with earth. Fumigate, and heat to 220° Fahr. (104°·5 C.), all clothes and bedding. As means of prevention attend especially to the purity of the drinking water, and to the disposal of sewage; although the origin of enteric fever merely from putrefying non-enteric sewage is not considered at present to be probable, it is not disproved, and it is certain that the disease may spread by the agency of sewers and fæcal decomposition. A single case of enteric fever should at once be held to prove that something is wrong with the mode of getting rid of the excretions. If neither water nor sewers can be proved to be in fault, consider the milk and other food supply.

Internal Causes.—As a first attack preserves in a great measure from a second, a peculiar condition of body is as essential as in smallpox; and looking to the special effect produced on Peyer's patches, and to the fact that at the period of life when these patches naturally degenerate, the susceptibility to typhoid fever materially lessens, or even ceases, it seems possible that the internal cause or necessary second condition is the existence of these patches, the structures in which are brought into an abnormal state of activity by the direct or indirect action of the poison on them. The other internal causes are anything which causes gastro-intestinal disorder, such as bad water, and general feebleness.

Relapsing Fever.

No preventive measures have been yet pointed out, but the occurrence of the disease in times of famine seems to indicate that feebleness and inanition are necessary internal causes. One attack seems to give no immunity from future attacks.[2]

Bilious Remittent Fevers.

Under this vague term a disease or diseases, which in many points are like relapsing fever, but yet are not identical (Marston), have been described as occurring especially in Egypt (Griesinger), and in the Levant generally. It has also been described by Drs Marston and Boileau[3] at Malta. The exact causes are not known; but in some of the writings of the older army surgeons the fevers which are produced by foul camps (in addition to enteric) appear to have a close resemblance to the bilious remittent fevers of the Mediterranean. They appear to be connected with bad sanitary conditions, but their exact causation is not clear.

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[1] Gietl., *Die Ursachen der enterischen Typhus in München*, 1865, pp. 74 and 94.

[2] The late Sir Robert Christison considered that an attack of *typhus* gave immunity from the *synocha* of the older nosologists, a disease apparently identical with relapsing fever.

[3] *Army Med. Reports*, vols. iii. and viii.

Cerebro-Spinal Meningitis.

This disease, which has occasionally been noticed in France, and especially among soldiers, for the last half century, has within late years appeared in several parts of Germany, and a few cases among civilians have occurred in England. It seems to depend on a specific agent, but very little is yet known about it. It does not appear to be contagious. No preventive measures can be at present suggested.

The Eruptive Fevers.

Smallpox is guarded against in the army by repeating vaccination in the case of recruits, and by occasional revaccination of all the men in a regiment. In the statistical reports, great attention is always paid to this important point, and the evidence from foreign armies proves the necessity of careful revaccination.

If the disease does occur, isolation[1] (in separate buildings) is most important, but the aggregating of a large number of cases together ought to be avoided.

In the case of scarlet fever and measles, nothing definite is known with regard to prevention, except that a good sanitary condition seems to lessen their intensity, and probably their spread. The evidence with regard to belladonna in scarlet fever is contradictory, but on the whole unfavourable. All the discharges should be disinfected, and the skin well rubbed over with camphorated oil and a little weak carbolic acid.

The most difficult case is when either measles or scarlet fever appears on board ship, and especially if children are on board. If the weather permit, the best plan is then to treat all patients on the upper deck under an awning. If this cannot be done (and scarlet fever patients must not be exposed to cold), they must be isolated as much as possible. Both in scarlet fever and smallpox there is some evidence to show that the incubative period may be very long.[2]

Perhaps, in the present state of evidence, it might be desirable to try the prophylactic effects of belladonna on board ship, directly the first case occurred.

Erysipelas (*Hospital or Epidemic*).

External Cause.—It is well known that in the surgical wards of hospitals erysipelas occasionally occurs, and then may be transmitted from patient to patient. The exact causes of its appearance have not been made out, but it is evidently connected with overcrowding and impure air. Moisture of the floors, causing constant great humidity of air, has also been supposed to aid it. It is much more common in fixed hospitals than in tents and huts, and indeed is exceedingly rare in the two latter cases. The agent or agencies can scarcely be supposed to be other than putrefying organic matter and pus cells passing into and accumulating in the air, or organisms developed in connection with them. It is remarkable that pus cells derived from purulent sputa do not cause erysipelas in medical wards, but this may be from a want of open wounds to give the necessary personal condition.

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[1] Buchanan gives a good example of the advantages of isolation in the case of Cheltenham, where smallpox was introduced into the town six times, but, in consequence of proper hospital accommodation for *all* classes, never made good its footing.

[2] See a case by Bryson (*Trans. Soc. Science Assoc.*, 1862, p. 677), for a case in which the incubative period of smallpox appeared to be thirty-one days. In scarlet fever it is said to be sometimes even longer, but this is very doubtful.

When hospital erysipelas has once appeared in a ward, nothing will avail except complete clearance of the ward, scraping the floors, and often the walls, washing with chloride of lime, and then with solution of caustic lime, and thorough fumigation with chlorine and nitrous acid alternately. The erysipelatous cases should be placed in well-ventilated tents.

Considering the undoubted beneficial influence of tent life, it may be a question whether, even in civil life, hospitals which possess gardens should not, during the summer, treat their surgical cases with suppurating wounds in the tents.[1] In many continental towns the large hospitals have now wooden huts attached to them, in which the surgical cases are treated.

Of course, extreme care in conservancy of wards or tents, the immediate removal of all dressings, great care in dressing wounds, so that neither by instruments, sponges, lint, or other appliances, pus cells or molecular organic matter shall be inoculated, are matters of familiar hospital hygiene. The use of carbolic acid and other antiseptics, as introduced by Professor Lister, has greatly lessened the chances of spread in the case of erysipelas as well as of hospital gangrene.[2]

Internal Causes.—Nothing is known on this point, except that there must be some abrasion or wound of the surface or of the passages near the surface, as the vagina or throat. The erysipelas commences at the point of abrasion. If there is no open wound, the atmospheric impurity seems to have no bad effect on the persons who are exposed to it, but it would be interesting to know if some forms of internal disease are not produced. Is it possible that some forms of tonsillitis and diphtheritic-like inflammation of the throat may be caused in this way, although there is no solution of continuity?

Hospital Gangrene.

Almost the same remarks apply to hospital gangrene as to erysipelas. One of the most important facts which has been pointed out by many writers, and which has been thoroughly proved by the American and the Italian wars, is that perfectly free ventilation prevents hospital gangrene. Hammond, the late Surgeon-General of the United States Army, declares[3] that only one instance has come to his knowledge in which hospital gangrene has originated in a wooden pavilion hospital, and not one which has occurred in a tent. Kraus also, from the experience of the Austrians in 1859, states that it never could be discovered that gangrene originated in a tent. On the contrary, cases of gangrene at once commence to improve when sent from hospital wards into tents. On the other hand, the tenacity with which the organic matters causing the gangrene adhere to walls is well known.

The measures to be adopted in wards when hospital gangrene occurs, and the ward cannot be at once evacuated, are the same as for erysipelas.[4] It is not necessary to do more than allude to the undoubted transference by dirty sponges, &c., and one of the many beneficial effects of antiseptic (or aseptic)

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[1] See Hammond's *Hygiene*, 1863; Kraus' *Das Kranken und Zerstreuungs-System*, 1861; and a Report on Hygiene, by Dr Parkes, in the *Army Medical Report* for 1862, for the effects of tents on erysipelas and hospital gangrene.

[2] I was informed, in Munich, that Lister's system has completely banished hospital gangrene from that city, and I believe the same result has been noticed in other German towns. —(F. de C.)

[3] *Hygiene*, p. 397.

[4] With regard to pyæmia, observations show that one of the external causes is fœtid organic emanations. Spencer Wells (*Med. Times and Gazette*, 1862), states that in 1859 the mortality from pyæmia was great in some wards over a dissecting room. On removing all the cases after operation to the opposite side of the building, pyæmia almost disappeared. Other similar cases are recorded.

dressings has been a more complete recognition of the value of scrupulous cleanliness, so that operations can now be performed without fear of result, so far as the above diseases are concerned, even without the use of aseptic dressings.

SECTION II.

VARIOUS NON-SPECIFIC DISEASES.

Dysentery and Diarrhœa.

At present there is no evidence that the dysentery arising from various causes has different anatomical characters, or runs a different course, except perhaps in the case of malarious dysentery. The chief causes are :—

1. *Impure Water.*—Both Annesley and Twining have directed attention to this cause in their accounts of Indian dysentery. It is scarcely possible that, with common attention, this cause should not be discovered and removed.

2. *Impure Air.*—The production of dysentery and diarrhœa from the effluvia of putrefying animal substances is an opinion as old as Cullen, and probably older, and there seems little doubt of its correctness. The gases and vapours from sewers also will, in some persons, cause diarrhœa; and also effluvia from the foul bilge-water of ships.[1] On the other hand, very disagreeable effluvia from many animal substances, as in the case of bone-burners, fat-boilers, &c., do not seem to cause diarrhœa. In India there appears to be a decided relation between the prevalence of dysentery and overcrowding and want of ventilation in barracks; massing a large number of men together is certainly an accessory cause of great weight.[2]

The air from very foul latrines has caused dysentery in numerous cases. Pringle, and many other army surgeons, record cases.[3] In war this is one of the most common causes. The occasional production of dysentery from sewage applied to land, seems to be proved by Clouston's observations on the cause of the attack of dysentery in the Cumberland Asylum.[4] Still, sewage matter has been often applied in this way without bad effects. In Dr Clouston's case the sewage was 300 yards from the ward where the dysentery occurred. Calm and nearly stagnant nights, or with a *gentle* movement of air from the sewage towards the ward, were the conditions which preceded most of the attacks.

Of all the organic effluvia, those from the dysenteric stools appear to be the worst. Some evidence has been given to show that dysentery arising from a simple cause (as from exposure to cold and wet), when it takes on the gangrenous form, and the evacuations are very fœtid, produces dysentery in those who use the latrines, or unclean closets, into which such gangrenous evacuations are passed. If correct, this is a most interesting point, as it seems to show the origin of a communicable poison *de novo*. Possibly, in all these cases, effluvia, or organic matters, or particles disengaged from the

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[1] Fonssagrives (*Traité d'Hygiène Navale*, p. 60) records a good case of this kind. It commenced after a gale at sea had stirred up the bilge, and on clearing it out the attack ceased.

[2] Wood on the *Health of European Soldiers in India*, 1864, p. 45 *et seq.*

[3] Sir James M'Grigor, Vignes (who gives many cases from the French experience in the Peninsula), Chomel, Copland; see also the *Dict. des Sciences Méd.*, art. "Dysentérie." D'Arcet (*Ann. d'Hygiène*, vol. xii. 390) records a good case, in which a whole regiment was affected, in the Hanoverian war, from having used too long the same trench as a latrine. The disease disappeared when another was dug.

[4] *Medical Times and Gazette,* June 1865.

putrefying evacuations, act at once on the anus, and the disease then spreads up by continuity.

There is some reason, also, to think that retaining dysenteric stools in hospital wards spreads the disease; and, perhaps, in this case, the organic particles floating up may be swallowed, and then act on the mucous membrane of the colon. In the epidemic of dysentery in Sweden in 1859, there was good evidence to show that it spread by means of the diarrhœal and dysenteric evacuations.[1] In all cases the stools must be mixed with disinfectants, and immediately removed from the wards and buried.

3. *Improper Food.*—Any excess in quantity, and many alterations in quality (especially commencing decomposition in the albuminoids, and, perhaps, the rancidity of the fatty substances) cause diarrhœa, which will pass into dysentery. But the most important point in this direction is the production of scorbutic dysentery. A scorbutic taint plays a far more important part in the production of dysentery than is usually imagined, and there is now no doubt that the fatal dysentery, which formerly was so prevalent in the West Indies, was of this kind. Much of the Indian dysentery is also often scorbutic.

4. *Exposure to Cold and Wet.*—Exposure to cold, especially after exertion, and extreme variations of temperature, have been assigned as the chief causes of dysentery by numerous writers;[2] great moisture has been assigned by some writers (Twining, Annesley, Griesinger) as a cause; and great dryness of the air by others (Mouat); while a third class of observers have considered the amount of moisture as quite immaterial.

Hirsch,[3] after summing up the evidence with respect to the temperature with great care, decides that sudden cold after great heat is merely a "*causa occasionalis*"[4] which may aid the action of the more potent cause of dysentery. This, probably, is the true reading of the facts. The amount of moisture in the atmosphere would appear to be a matter of no moment.

Although we cannot assign its exact causative value, the occurrence of chill is, of course, as a matter of prudence, to be carefully guarded against, and especially chills after exertion. It is when the body is profusely perspiring, and is then exposed to cold, that dysentery is either produced, or that other causes are aided in their action. In almost all hot countries chilling of the abdomen is considered particularly hurtful, and shawls and waist-bands (kamarband of India) are usually worn.[5]

5. *Malaria* has been assigned as another cause; and it was noticed especially by the older writers, that the dysentery was then often of the kind

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[1] *British and Foreign Med. Chir. Rev.*, Jan. 1866, p. 140.

[2] A few only can be noted; Stoll, Zimmermann, Huxham, Durandeau, Willan, Irvine, James Johnson, Annesley, Bampfield, Morehead, Vignes, Fergusson, &c. Fergusson says: "True dysentery is the offspring of heat and moisture; of moist cold in any shape after excessive heat. Nothing that a man can put into him would ever give him true dysentery."

[3] *Handbuch der Historisch-Geograph. Pathol.*, Band ii. p. 234.

[4] The so-called "hill diarrhœa," which was formerly prevalent on some of the hill sanitaria in India, especially on the spurs of the Himalayas, has been attributed to the effect of cold and moisture, and sudden changes of temperature. But, as remarked by Dr Alexander Grant, many hill stations have these atmospheric conditions without having any hill diarrhœa. There is great reason to suppose the hill diarrhœa to be entirely unconnected with either elevation or climate. In some cases it has been clearly caused by bad water, possibly by suspended scales of mica or by magnesian salts in the water; in other cases, its exact causes remained unexplained. Of late years it has lessened in amount at all stations, and will probably disappear.

[5] It is a remarkable circumstance, that in temperate climates the most common months for dysenteric epidemics are the hot months—June to September. Taking North America and Northern and Western Europe, Hirsch has assembled 546 outbreaks. Of these, 176 occurred in summer; 228 in summer and autumn; 107 in autumn; only 16 in spring; and 19 in winter. This does not look as if cold had any effect. The heat of summer is far more influential.

termed "*Dysenteria Incruenta*"—the stools being copious, serous, and with little blood; in fact, a state somewhat resembling cholera.

Very great difference of opinion has prevailed in regard to this opinion.[1] Possibly the "malarious dysentery" is in part connected with the use of marsh water. More evidence is desirable, certainly, with regard to this point; but it seems probable, from the observations of Annesley and Twining, that marsh water has an effect in this direction.

Liver Diseases (Indian).

The production of diseases of the liver is so obscure, and so many states of hepatic disorder are put together under the term "hepatitis," that it is impossible to treat this subject properly without entering fully into the question of causes. But, as this could not be done here, we must content ourselves with a short summary of the preventive measures which appear to be of the greatest importance.

Dr Parkes had long been convinced that many cases of hyperæmia, bilious congestion, and enlargement of the liver, with increase of cell-growth and connective tissue (but without tendency to abscess), and enlargement and partial fatty degeneration of the liver cells, are caused simply by diet.[2] He had a good opportunity of observing this on landing in India in 1842 with an European regiment,[3] and his later experience made him certain that the observation was correct.

Very similar opinions have been expressed by Macnamara,[4] and Norman Chevers also pointedly alluded to this subject.[5]

The supply of food for the soldier in India has erred in two ways: it is too much in quantity, especially when the amount of exercise is limited. Macnamara has calculated that each European soldier in Bengal consumed (at the time he wrote in 1855) 76 ounces of solid (*i.e.*, water-containing) food daily, so that there must have been an excess of all the dietetic principles. Then, in every case, there was added to this a very large amount of condiments (spices and peppers), articles of diet which are fitted for the rice-and-vegetable diet of the Hindu, but are particularly objectionable for Europeans. In the West Indies, where the diet has never been so rich in condiments, liver diseases have always been comparatively infrequent.

Some orders for improving the cooking in India were issued by Lord Strathnairn, and if these were carried out, and if medical officers would thoroughly investigate the quantity of food taken by the men, and compare it with their work, and examine into the cooking, it is quite certain that many cases of dyspepsia and hepatitis would be prevented.

In cases not simply of hyperæmia and bilious congestion, but of abscess, it is probable that a certain number are consecutive to dysentery, and are caused by the absorption of putrid matters from the intestine,[6] which are

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[1] The very varying opinions are given very fully by Hirsch. Morehead's great authority was altogether against the presumed action of malaria; but possibly here, as in many other cases, we shall have to draw a complete distinction between malarious and non-malarious dysentery.

[2] In the great and admirable works of Ranald Martin and Morehead, the influence of diet in producing liver affections, though alluded to, has been passed over much too lightly. Annesley, on the other hand, has fully recognised the immense influence of diet (vol. i. p. 192).

[3] *Remarks on the Dysentery and Hepatitis of India*, by E. A. Parkes, M.B., 1846, p. 228.

[4] *Indian Annals*, 1855. Dr Macnamara found a most extraordinary amount of fatty degeneration of the liver.

[5] "Health of European Troops in India," *Indian Annals*, 1858, p. 109. It is particularly recommended that this chapter should be carefully perused.

[6] It is, however, remarkable how many cases of dysentery occur without producing hepatic abscess; still our general knowledge of the causation of disease makes it highly probable that dysentery acts in this way. Is it the sloughing dysentery which is followed by hepatic abscess?

arrested by the liver, and there set up suppuration. There is no true pyæmia or inflammation of the vena portæ as a rule. When caused by phlebitis or special affection of the vena portæ, the suppuration is in the course of the vena portæ, or at any rate commences there. The reason why some cases of dysentery cause abscess and others do not is uncertain. The prevention of this form of abscess is involved in the prevention of dysentery.

In other cases of abscess, however, there is no antecedent dysentery, but there are collections of pus or fœtid débris somewhere else, which act in the same way by allowing absorption. There are, however, other cases in which no such causes have been pointed out, and the genesis of these cases of abscess remains quite obscure. Much effect has been attributed to the influence of sudden changes of temperature; to the rapid supervention of an exceedingly moist and comparatively cold air on a hot season, whereby the profuse action of the skin is suddenly checked; and to the influence of malaria. But the extraordinary disproportion of cases of abscess in different parts of the world seems to negative all these surmises.

One fact seems to come out clearly from Dr Waring's observations, viz., that recent arrival in India is favourable to the occurrence of abscess, and that (all kinds of abscesses being put together) 50 per cent. occur in men under three years' service. No length of residence, however, confers perfect immunity. It would be very important to determine whether the effect of recent arrival is marked, both in cases of abscess consecutive, and in those anterior, to dysentery.

It is possible, also, that some entozoic influence may be at work, especially in some parts of India, and hydatid disease of the liver or other diseases of the same class may be more common than is supposed.

In the absence of perfect knowledge, great care in preserving from chills, and proper diet, are the only preventive measures which can be suggested for primary hepatic abscess.

Insolation.

Under this convenient term, a number of cases are put together which seem to be produced by one or more of the following causes:—

External Causes.—1. Direct rays of the sun on the head and spine. Adopt light coverings, covered with white cotton; permit a good current of air between the head and the covering, and use a light muslin or cotton rag, dipped in water, over the head under the cap. 2. Heat in the shade, combined especially with stagnant and impure air. In houses (and men have been attacked with insolation both in tents and barracks) means can always be taken to move the air, and thus keep it pure, even if it cannot be cooled. In tents the heat is often exceedingly great, simply from the fact that there is not sufficient movement of air; in the tropics a simple awning is much better than tents, and if the awning is sloped a little, the top of the slope being towards the north, the movement of air will be more rapid than if the canvas be quite flat. But in the dry season, in the tropics, the men should sleep in the open air in all non-malarious districts, when they are on the march or in campaigns.

The general prophylaxis has been thus summed up by Professor Maclean:[1] —"Men will bear a high temperature in the open air with comparative impunity, provided (*a*) it is not too long continued; (*b*) that the dress be

[1] Reynolds' *System of Medicine*, vol. ii. p. 157. See also *Diseases of Tropical Climates*, by the same author, Macmillan & Co., 1886.

reasonably adapted to the temperature; (c) that the free movement of the chest be not interfered with."

Internal Causes.—It is only known that spirit drinking, even in moderation, powerfully aids the external causes of insolation; even wine and beer probably have this effect. Tea and coffee, on the other hand, probably lessen the susceptibility.

A full habit of body, or any tendency to fatty heart or emphysematous lungs, have been supposed also to predispose.

It seems certain that any embarrassment of the pulmonary circulation aids the action of the heat, and therefore the most perfect freedom from belts and tight clothes over the chest and neck is essential.

Great exhaustion from fatigue aids the action, either from failure of the heart's action or want of water. In this case diffusible stimuli, such as ammonia, tincture of red lavender, tincture of cardamoms, &c., with strong coffee, are the best preventives. Spirits should not be given, unless the exhaustion be extreme, and the diffusible stimuli cannot be obtained. A small quantity in hot water may then be tried.

Cold baths, and especially cold douching to the head and spine, are most useful as preventive as well as curative measures.

Phthisis Pulmonalis.

In respect of causes, we must distinguish those usually rapid cases of tuberculosis which arise from hereditary constitutional causes, or from the influence of exanthemata (especially measles), or of enteric or other fevers, and which run their course with implication of several organs at an early stage, and the more chronic forms of phthisis, in which the lung in adults is the first seat of the disease, and other organs are secondarily affected. Several distinct diseases are confounded under the one term of phthisis, and it is therefore not possible at present to trace out their precise origin.

Taking only the common cases of subacute or chronic phthisis, it has been already intimated that most European armies have been found to furnish an undue proportion of such cases.[1]

Some years ago much influence was ascribed to food as a cause of phthisis; the occurrence of a sort of dyspepsia as a forerunner (though this does not seem very common), and the great effect of the treatment by diet (by cod-liver oil), seemed to show that the fault lay in some peculiar malnutrition, which affected the blood, and through this the lungs.

Probably there is truth in this; but of late years the effects of conditions which influence immediately the pulmonary circulation and the lungs themselves have attracted much attention. The effect of want of exercise (no doubt a highly complex cause, acting on both digestion and circulation), and of impure air, have been found to be very potent agencies in causing phthisis, and, conversely, the conditions of prevention and treatment which have seemed most useful are nutritious food and proportionate great exercise in the free and open air. So important has the last condition proved to be, that it would appear that even considerable exposure to weather is better than keeping phthisical patients in close rooms, provided there be no bronchitis or tendency to pneumonia or pleurisy.

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[1] There are two valuable pieces of evidence of phthisical and scrofulous disease being developed in a healthy population from impure air, viz., Mr Morgan's essay on "Phthisis on the West Coast of Scotland" (*Brit. and For. Med.-Chir. Rev.*), and the analogous case of Western Canada, given by Mr Mackeleave (*Medical Times and Gazette*, Aug. 1868).

Three points, then, are within our control as regards phthisis—arrangement of food, exercise, and pure air.

That food should contain a good deal of the nitrogenous and fatty principles if phthisis is apprehended. Milk has been long celebrated, and lately the koumiss of Tartary has obtained a great reputation in Russia as an agent of cure, and is now a good deal used (made from cow's milk) in this country.

Exercise is of the greatest importance, and it would seem quite clear that this must be in the open air. The best climates for phthisis are perhaps not necessarily the equable ones, but those which permit the greatest number of hours to be passed out of the house.

In the house itself, attention to thorough ventilation, *i.e.*, to constant, though imperceptible movement of the air, is the point to be attended to.

In the case of soldiers, it must also be seen that no weights or straps impede the circulation of blood through the lungs and heart.

The effect of a wet subsoil in the causation of phthisis must not be overlooked. Whatever may be the exact amount of truth, we are bound to act as if it were certain.

That syphilitic disease of the lungs has sometimes a completely phthisical character is tolerably clear, but syphilis will not account for the amount of phthisis in the army. The influence of masturbation in producing phthisis is uncertain.

The researches of Koch, and the discovery of *Bacillus tuberculosis*, have revived the notion of the communicability of the disease, an idea long held by Italian physicians. This would only be a still greater argument for the freest ventilation indoors, and for a large part of the patient's time being spent out of doors. It would also indicate the inadvisability of allowing healthy individuals (especially children) to sleep with or occupy the same sleeping rooms as phthisical persons. It would also be an argument against massing phthisical patients together, although there does not seem to be any direct evidence of injury arising from consumption hospitals, which are, however, always freely and carefully ventilated.

As regards Army phthisis, Dr Lawson has called attention to some important points in a paper read before the Statistical Society.[1] He points out that 78 per cent. of the cases are inflammatory in origin, according to Welch, and shows that the variations in the amount of phthisis have been coincident with changes in the clothing, such as the adoption and abolition of white duck trousers, and the introduction of woollen underclothing. He argues, therefore, that chills have had even more to do with it than foul air. But the latter was probably a powerful agent in rendering the soldier susceptible to the former.

Scurvy.

The peculiar state of malnutrition we call scurvy is now known not to be the consequence of general starvation, though it is doubtless greatly aided by this. Men have been fed with an amount of nitrogenous and fatty food sufficient not only to keep them in condition, but to cause them to gain weight, and yet have got scurvy. The starches also have been given in quite sufficient amount without preventing it. It seems, indeed, clear that it is to the absence of some of the constituents of the fourth dietetic group, the salts, that we must look for the cause.[2]

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1 *Journal of the Statistical Society*, January 1887.

2 For a good deal of evidence up to 1848, reference may be made to a Review on Scurvy, contributed by Dr Parkes to the *British and Foreign Medico-Chirurgical Review* in that year.

Facts seem to show with certainty that in the diet which gives scurvy there is no deficiency of soda or of iron, lime, or magnesia, or of chloride of sodium. Nor is the evidence that salts of potash or phosphoric acid are deficient at all satisfactory. And when we think of the quantity of phosphoric acid which must have been supplied in many diets of meat and cerealia, which yet did not prevent scurvy, it seems very unlikely that the absence of the phosphates can have anything to do with it.[1]

The same may be said of sulphur. Considering the quantity of meat and of leguminosæ which some scorbutic patients have taken, it is almost impossible that deficiency in sulphur should have been the cause.

By exclusion, we are led to the opinion that if the cause of scurvy is to be found in deficiency of salts, it must be in the salts whose acids form carbonates in the system. For, if we are right in looking to a deficiency in the fourth class of alimentary principles as the cause of scurvy, and if neither the absence of soda, potash, lime, magnesia, iron, sulphur, or phosphoric acid can be the cause, then the only mineral ingredients which remain are the combinations of alkalies with those acids which form carbonates in the system, viz., lactic, citric, acetic, tartaric, and malic. That these acids are most important nutritional agents no one can doubt. The salts containing them are at first neutral, afterwards alkaline, from their conversion into carbonates; they thus play a double part, and, moreover, when free, and in the presence of albumen and chloride of sodium, these acids have peculiar powers of precipitating albumen, or perhaps of setting free hydrochloric acid. Whatever may be their precise action, their value and necessity cannot be doubted. Without them, in fact, one sees no reason why there should not be a continual excess of acid in the system, as during nutrition a continual excess of acids (phosphoric, sulphuric, uric, hippuric) is produced, sufficient, even when the salts with decomposable acid are supplied, to render all excretions (urinary, cutaneous, intestinal) acid. The only mode of supplying alkali to the acids formed in the body is by the action of the phosphates, which is limited. The only manufacture of alkali in the body is the formation of ammonia, so that these salts are most important as antacids. Yet it is not solely the absence of alkali which produces scurvy, else the disease would be prevented or cured by supply of pure or carbonated alkalies, which is not the case.

When, in pursuing the argument, we then inquire whether there is any proof of the deficiency of these particular acids and salts from the diets which cause scurvy, we find the strongest evidence not only that this is the case, but that their addition to the diet cures scurvy with great certainty.[2] They

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The evidence since that period has added little to our knowledge, except to show that the preservative and curative powers of fresh meat in large quantities, and especially raw meat (Kane's Arctic Expedition), will not only prevent, but will cure scurvy. Kane found the raw meat of the walrus a certain cure. For the most recent evidence and much valuable information, see the *Report of the Admiralty Committee on the Scurvy which occurred in the Arctic Expedition of* 1875-76 (Blue-Book, 1877).

[1] Professor Galloway, of Dublin, and Mr Anderson, of Coventry, have both written pamphlets urging the claims of potash and phosphoric acid to attention, but without bringing any fresh evidence of sufficient importance to support their views.

[2] This was most clearly shown in the last Arctic Expedition (1875-76). The rations on board ship during winter were ample, containing dried potatoes and other vegetables, preserved vegetables, pickles, bottled fruits, vinegar, and a daily ration of lime juice, besides raisins and currants. In the sledge expeditions all these were cut off except two ounces of preserved potatoes, an inadequate ration under any circumstances. The meat was pemmican and bacon, and there was, of course, no fresh bread. The result was that this imperfect diet, conjoined with most laborious work, produced a severe outbreak of scurvy, which nearly proved fatal to the whole party. The rapidity with which the sick recovered on being supplied with lime juice and more favourable diet, was noticeable (see *Report, op. cit.*).

Cases are occasionally reported in which even fatal results are said to have taken place in

will not, of course, cure coincident starvation arising from deficiency of food generally, or the low intercurrent inflammations which occur in scurvy, or the occasionally attendant purpura, but the true scorbutic condition is cured with certainty.

Of the five acids, it would appear unlikely that the lactic should be the most efficacious. If so, how is it that in starch food, during the digestion of which lactic acid is probably formed in large quantities, scurvy should occur? Is, in such a case, an alkali necessary to insure the change of the acid into a carbonate?

Vinegar is an old remedy for scurvy, and acetic acid is known to be both a preventive of (to some extent) and a cure for scurvy. But it has always been considered much inferior to both citric and tartaric acids. Possibly, as in the case of lactic acid, an alkali should be supplied at the same time, so as to enable the acid to be more rapidly transformed.

Tartaric and (especially) citric acids, when combined with alkalies, have always been considered to be the antiscorbutic remedies *par excellence*, and the evidence on this point seems very complete.[1]

Of malic acid little is known as an antiscorbutic agent, but it is well worthy of extended trials.

Deficiency of fresh vegetables implies deficiency in the salts of these acids, and scurvy ensues with certainty on their disuse. Its occurrence is, however, greatly aided by accessory causes, especially deficiency in food generally, by cold and wet, and mental and moral depression.

The preventive measures of scurvy are, then, the supply of the salts of citric, tartaric, acetic, lactic, and malic acids, and of the acids themselves, and perhaps in the order here given, and by the avoidance, if it can be done, of the other occasional causes.

Experience seems to show that the supply of these acids in the juices of the fresh succulent vegetables and fruits, especially the potato, the cabbage, orange, lime, and grape, is the best form. But fresh fruits, tubers, roots, and leaves are better than seeds. The leguminosæ, and many other vegetables, are useless; so also are the cereals.

Fresh, and especially raw meat is also useful, and this is conjectured to be from its amount of lactic or paralactic acid; but this is uncertain.

The dried vegetables are also antiscorbutic, but far less so than the fresh; and the experience of the American War was not so favourable to them as might have been anticipated. Do the citric and other acids in the dried vegetables decompose by heat or by keeping? It would be very desirable to have this question settled by a good chemist. We know that the citric

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spite of sufficient vegetable diet (see Dr Guillemard's *Cruise of the Marchesa*, vol. ii. p. 353). Unless such cases are recorded with much greater fullness of detail than is usually done, but little value can be attached to them. At the same time it is well not to lose sight of possible exceptions to the rule that vegetable diet of the proper kind is a pretty certain cure for, as well as prophylactic against, true scurvy.

[1] It is based on a very wide experience, and should not be set aside by the statements of men who have seen only three or four cases of scurvy, often complicated, which happen not to have been benefited by lemon juice. The process of preventive medicine is checked by assertions drawn from a very limited experience, yet made with great confidence. We must remember that many cases of scurvy are complicated—that the true scorbutic condition, inanition, and low inflammation of various organs, lungs, spleen, liver, and muscles, may be all present at the same time. See paper by Dr Ralfe, of the Seamen's Hospital (1877, reprinted from the *Lancet*). The Merchant Shipping Act of 1867 was soon followed by a great decrease of scurvy in our mercantile marine; but since 1873 there has been a steady increase, which has been attributed by Mr Thomas Gray (see Official Memorandum on *Sea Scurvy and Food Scales*, 1882) to want of more varied food scales. It may, however, have resulted from neglect of lime juice, or the use of a damaged article (see *British Medical Journal*, Sept. 1882).

acid in lemon juice gradually decomposes. It does not follow that it should be quite stable in the dried vegetables.

The measures to be adopted in time of war, or in prolonged sojourn on board ship, or at stations where fresh vegetables are scarce, are—

1. The supply of fresh vegetables and fruits by all the means in our power. Even unripe fruits are better than none, and we must risk a little diarrhœa for the sake of their antiscorbutic properties. In time of war *every* vegetable should be used which it is safe to use, and, when made into soups, almost all are tolerably pleasant to eat. Even the skins of many fruits, bruised and made into a drink with water, are useful.

2. The supply of the dried vegetables,[1] especially potato, cabbage, and cauliflowers; turnips, parsnips, &c., are perhaps less useful; dried peas and beans are useless. As a matter of precaution these dried vegetables should be issued early in a campaign, but should never supersede the fresh vegetables.

3. Good lemon juice should be issued daily (1 oz.), and it should be seen that the men take it.

4. Vinegar ($\frac{1}{2}$ oz. to 1 oz. daily) should be issued with the rations, and used in the cooking.

5. Citrates, tartrates, lactates, and malates of potash should be issued in bulk, and used as drinks, or added to the food. Potash should be selected as the base, as there is seldom any chance of the supply of soda being lessened. The easiest mode of issuing these salts would be to have packets containing enough for one mess of twelve men, and to instruct the men how important it is to place them in the soups or stews. Possibly they might be mixed with the salt, and issued merely as salt. Lozenges made of citric acid or desiccated lime juice and sugar are well worth a trial.

Military Ophthalmia.

The term "military ophthalmia" is often applied particularly to that disease in which the peculiar grey granulations form on the palpebral conjunctiva. But any severe form of purulent ophthalmia spreading in a regiment is often classed under the same heading. Diseases of the eyes are a source of very considerable inefficiency in the army, and even a casual visitor to the Royal Victoria Hospital must be struck by the large number of men he will meet with who have some affection of the eyes. A reference to the *Army Medical Reports* will also show what great attention is being paid to this important subject by military surgeons, especially by Sir Thomas Longmore.[2]

Epidemics of military ophthalmia (grey or vesicular granulations, and rapid purulent ophthalmia) seem to have been uncommon, or perhaps unknown, on the large scale in the wars of the eighteenth century.

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[1] Probably dried fruits, such as raisins and currants (which contain some acid and vegetable salts) are useful as antiscorbutics. The American pemmican contains them, and men are said to live upon it for months together without suffering from scurvy. It appears to have been that kind of pemmican on which the crew of the "Polaris" lived, who drifted on an iceberg for six months. Other dried fruits, such as apples, would probably also be efficacious.

[2] Ophthalmoscopes are now issued to the different stations, and an *Ophthalmoscopic Manual* has been drawn up by Sir Thomas Longmore for the use of army medical officers. As giving a good survey of military ophthalmia in the British army, the excellent papers of Dr Frank (*Army Medical Report* for 1860) and Dr Marston (Beale's *Archives*) should be also referred to. A very interesting paper has also been published by Mr Welch (Medical Staff, formerly 22nd Regiment) (*Army Medical Report*, vol. v. p. 494, 1865), on the "Causes aiding the Development of Granulations at Malta." A warm, moist, impure atmosphere is shown to have a great influence.

The disease, as we now see it, is one of the legacies which Napoleon left to the world. His system of making war with little intermission, rapid movements, abandonment of the old custom of winter quarters, and intermixture of regiments from several nations, seem to have given a great spread to the disease; and though the subsequent years of peace have greatly lessened it, it has prevailed more or less ever since in the French, Prussian, Austrian, Bavarian, Hanoverian, Italian, Spanish, Belgian, Swedish, and Russian armies, as well as in our own. It has also been evidently propagated among the civil population by the armies, and is one more heritage with which glorious war has cursed the nations. Our last Egyptian campaign (1882), which was very short, does not appear to have produced much ophthalmia among the troops engaged, and no case of loss of vision occurred.

In some cases, as in the Danish army, it has been absent till manifestly introduced (in 1851); in other instances it has been supposed to originate spontaneously from overcrowding and foul barrack atmosphere, and from defective arrangements for ablution.[1] Here, as in so many other cases, we find that the question of origin *de novo*, however important, need not be mixed up with that of the necessary preventive measures. What is important for us is to know—*first*, that it is contagious, that is, transmissible; and, *secondly*, that, if not produced, its transmissibility is singularly aided by bad barrack accommodation.

The measures to be adopted if military ophthalmia prevails—

1. *Good Ventilation and Purity of the Air.*—In the Hanoverian army, Stromeyer reduced the number of cases in an extraordinary degree, simply by good ventilation. The only explanation of this must be, that the dried particles of pus and epithelium, instead of accumulating in the room, were carried away, and did not lodge on the eyelids of the healthy men. The evolution of ammonia from decomposing urine has also been assigned as a cause, and this would also be lessened by good ventilation.

It would appear likely that bad barrack air predisposes to granular conjunctivitis by producing some peculiar state of the palpebral conjunctiva and glands (Stromeyer and Frank), and if a diseased person then introduces the specific disease, it spreads with great rapidity, or possibly, as Mr Welch's facts seem to show, the impure atmosphere is the great cause, and contagion only secondary.

2. *Careful Ablution Arrangements.*—An insufficient quantity of water for cleansing basins, and the use of the same towels, are great means of spreading the disease if it has been introduced. Whenever men use the same basins, they should be taught to thoroughly cleanse them; and it would be well if, in every military ablution room, the men were taught not only to allow the dirty water to run away, but to refill the basin with water, which the next comer would let off before filling with fresh water for himself. If some mechanism could be devised for this, it would be very useful. The same towel is a most common cause of propagation; or a diseased man using always the same towel may reinoculate himself. The towels should be very frequently washed (probably every day), and should be dried in the open air, never in the ablution room or barrack.

In some cases special ablution arrangements may cause a good deal of granular conjunctivitis. In 1842 and 1843 Dr Parkes witnessed, in a regiment newly landed in India from England, a very great number of

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[1] See Frank's papers (*Army Medical Report* for 1860, p. 406) for some remarks on its spontaneous origin.

cases of this kind. The supply of water was very insufficient, many men used the same basins, which were very imperfectly cleaned; the same basins were used for washing, and also for dyeing clothes: at that time the men in the cold months wore trousers of a black drill, and when the dye came off they were accustomed to rudely replace it; they themselves ascribed the very prevalent ophthalmia to the irritating effect of the particles of the dye left in the basins, and getting into the eyes. There were enormous granulations on both upper and lower lids, and the disease was believed to be communicable, but whether the affection was strictly to be classed with the vesicular granulations is not known.

3. In some cases the use of the bedding (pillows and pillow cases) which has been used by men with grey granulations has given the disease to others, and this has especially occurred on board transports. In time of war especially this should be looked to. If any cases of ophthalmia have occurred on board ship, all the pillows and mattresses should be washed, fumigated, and thoroughly aired and beaten. The transference has been in this case direct, particles of pus, &c., adhering to the pillow and mattresses, and then getting into the eyes of the next comers.

4. Immediately the disease presents itself, the men should be completely isolated, and allowed to have no communication with their comrades. It has been a great question whether a Government is justified in sending soldiers home to their friends, as the disease has been thus carried into previously healthy villages. It would seem clear that the State should bear its own burdens and provide means of isolation and perfect cure, and not throw the risk on the friends and neighbours of the soldier.

An important matter to remember in connection with grey granulations is, that relapses are very frequent; a man once affected has no safety (Warlomont); simple causes of catarrh and inflammation may then reinduce the specific grey granulations with their contagious characters; so that a man who has once had the disease is a source of danger, and should be watched.

Venereal Diseases in the Army.

It is convenient for our purpose to put together all diseases arising from impure sexual intercourse, whether it take the form of sore or of urethral discharge.

In the army, men enter the hospital from these causes, and from the remoter effects of gonorrhœa or syphilis, orchitis, gleet, stricture, bladder and kidney affection; or syphilitic diseases of the skin, bones, eyes, and internal organs.

The gross amount of inefficiency in the army is tolerably well known, but the comparative amount of army and civil venereal diseases is not known, because we have no statistics of the civil amount. It is no doubt great. It is a question whether a large majority of the young men of the upper and middle classes do not suffer in youth from some form of venereal disease. In the lower classes it is perhaps equally common.

The sequences are most serious; neglected gleet, stricture, secondary and tertiary syphilis, are sad prices to pay for an unlawful (in some cases a momentary) gratification; and in the army the State yearly suffers a large pecuniary loss from inefficiency and early invaliding. In campaigns the inefficiency from this cause has sometimes been great enough to alarm the generals in command, and to increase considerably the labour and sufferings of the men who are not affected.

The preventive measures against venereal diseases are:—

1. *Continence.*—The sexual passion in most men is very strong—strong enough indeed to lead men to defy all dangers, and to risk all consequences. It has been supposed by some that, in early manhood, continence is impossible, or, if practised, is so at the risk of other habits being formed which are more hurtful than sexual intercourse, with all its dangers. But this is surely an exaggeration; the development of this passion can be accelerated or delayed, excited or lowered, by various measures, and continence becomes not only possible, but easy.

For delaying the advent of sexual puberty and desire, two plans can be suggested—absence from exciting thoughts and temptation, and the systematic employment of muscular and mental exercise. The minds of the young are often but too soon awakened to such matters, and obscene companions or books have lighted up in many a youthful breast the *feu-d'enfer* which is more dangerous to many a man than the sharpest fire of the battlefield would be. Among young soldiers this is especially the case; while, in spite of the exciting literature of the day, and of the looseness of some of the older boys at the public schools, or at the universities, the moral tone of the young gentlemen of our day is better than it was some half century ago, the conversation of the classes from which the soldier is drawn is still coarse and lewd as in the middle ages. There is too close a mixture of the sexes in the English cottages for much decency, and the young recruit does not often require the tone of the barrack to destroy his modesty. In fact, it is possible that, in good regiments, he will find a higher moral tone than in the factory or the harvest field.

We must trust to a higher cultivation and moral training to introduce among the male youth of this nation, in all its grades, a purer moral tone. In the army, the example of the officers, and their exertions in this way, would do great things, if we could hope that the high moral tone which happily exists in some cases could inspire all.

It is not the less necessary to save the young from direct temptation. The youth of this nation are now sorely tempted, for in our streets prostitution is at every corner. Whatever may be the objection to police regulations, we have surely a right to demand that the present system of temptation shall be altered. It may not be easy to exclude all prostitutes, especially of the better class (whose calling is less easily brought home to them), from public thoroughfares, but, practically, open prostitution can be recognised and made to disappear from our streets. It has been said our police regulations are sufficient for this; they have never yet proved so; and in no European country but England is prostitution so open and so undisguised.[1]

In the Acts passed in 1864,[2] 1866, and 1869, and in the Licensing Act of 1872, authority was taken to prevent prostitutes from assembling in the public-houses, and to a certain extent sources of temptation were removed. Unfortunately, the legislature, listening to the senseless outcry of a section of the population, has since repealed those important Acts.

As aids to continence, great physical and mental exertion are most powerful. It would seem that, during great exercise, the nervous energy

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[1] The effect of this upon the virtuous female population is very serious. Every servant in London sees the fine clothes and hears of the idle luxurious lives of the women of the town, and knows that occasionally respectable marriage ends a life of vice. What a temptation to abandon the hard work and the drudgery of service for such a career, of which she sees only the bright side! It is a temptation from which the State should save her. She should see prostitution as a degraded calling only, with its restrictions and its inconveniences.

[2] *An Act for the Prevention of Contagious Diseases at Certain Naval and Military Stations*, 1864; an *Act for the Better Prevention, &c.*, 1866 (cited as *Contagious Diseases Act*, 1866). All these are now repealed.

is expended in that way, and erotic thoughts and propensities are less prominent; so also with mental exercise, in perhaps a less degree. The establishment of athletic sports, gymnasia, and comfortable reading-rooms in the army may be expected to have some influence.

Temperance is a great aid to continence. In the army the intemperate men give the greatest number of cases of syphilis; and when a man gets an attack, it is not infrequently found that he was drunk at the time.

The measures which promote continence are then—

(*a*) The cultivation of pure thought and conversation among the young soldiers, by every means in our power.

(*b*) Removing temptation.

(*c*) Constant and agreeable employment, bodily and mentally; as idleness is one great cause of debauchery.

(*d*) Temperance.

2. *Marriage.*—It is very doubtful whether those who condemn early marriages among the working classes, on account of improvidence, are entirely right in their argument. The moral effect of prolonged celibacy has seldom been considered by them. Probably the early marriages are the salvation of the working youth of this country; and in the present condition of the labour market, the best thing a working man can do is as early as possible to make his home, and to secure himself both from the temptations and expenses of bachelorhood. In the case of the soldier the conditions were formerly different for different men; the private soldier who had enlisted for long service (twelve years, and prospect of renewal) could not marry for seven years, and then only 7 per cent. could marry with leave. It was difficult to avoid this, and the consequences were certainly most serious. Under the new system of seven years' enlistment, and passage into the reserve, a soldier will not marry at all, and it is of course desirable he should not do so. If he enlists at nineteen, at twenty-six he will be free; and if kept in full occupation, and as far as possible shielded from temptation, the burden of celibacy will not weigh upon him. Continence would be desirable for his health, and for the welfare of his future offspring. The short service now introduced may indeed greatly influence this matter, and certainly has removed from pressing discussion the question of marriage in the infantry of the army.

3. *Precautions against the Disease.*—Admitting that, in the case of a body of unmarried men, a certain amount of prostitution will go on, something may be done to prevent disease by extreme cleanliness, instant ablution, and by the use of zinc, alum, and iron washes, or similar lotions after connection, and by the constant use by prostitutes of similar washes. It may seem an offence against morality to speak of such things; but we must deal with things as they are; and our object now is not to enforce morality, but to prevent disease. The use in brothels of these measures appears to be more efficacious than any other plan. In some of the French towns the use of lotions and washings is rigorously enforced, with the effect of lessening disease considerably.

4. *Detection and Cure of Diseased Men and Women.*—In the case of the soldier who has medical advice at hand, it seems of the greatest importance to have instant medical aid at the first sign of disease. But, instead of this, the soldier conceals his ailment as long as possible, because he will be sent to hospital, put under stoppages, &c. A late regulation made this even more stringent, but it is now happily rescinded. The soldier should be encouraged to make immediate application, and he should certainly not be punished for a fault which his superiors commit with impunity, and for

which the State is in part answerable by enforcing celibacy. Our object is to preserve the man's health and services for the State; we shall not accomplish this by ignoring what is a common consequence of his conditions of service.

It has been proposed to detect and cure the disease in prostitutes. A great outcry has been raised against this proposal, which is yet a matter of precaution which the State is surely bound to take. A woman chooses to follow a dangerous trade—as dangerous as if she stood at the corner of a street exploding gunpowder. By practising this trade she ought at once to bring herself under the law, and the State must take what precautions it can to prevent her doing mischief. The State cannot prevent prostitution. We shall see no return to the stern old Scandinavian law which punished the prostitute with stripes and death; but it is no more interference with the liberty of the subject to prevent a woman from propagating syphilis than it would be to prevent her propagating smallpox.

This interference with the propagation of venereal disease is now unhappily at an end, and all the Acts for the purpose are erased from the Statute Book,[1] the compulsory examination having been previously abolished in May 1883.

After the passing of these Acts there was a most decided decrease in the number of primary venereal sores at all the military stations under the Acts, compared with non-protected stations.[2] And this was the more satisfactory because the frequent movement of the troops, and the number of stations where there was no control of disease, rendered the working of the Acts difficult.[3]

The following figures, from the *A. M. D. Report* for 1882, the last year of complete operation of the Acts, are quite convincing.

In 1882 there were fourteen stations under the Contagious Diseases Act, with a mean strength of 41,783 men; putting against these all other stations not under the Act, with an average strength of 45,064 men, we have the following ratio :—

Admission per 1000 of Strength.

	Primary Venereal Sore.	Gonorrhœa.
Fourteen stations, under the Act, 1882, .	78	100
All other stations, not under the Act, 1882, .	124	112

[1] Those persons who shut their eyes to the enormous prostitution of this country, as of all others, or think nothing can be done because it is impossible to deal with private or "sly" prostitution, and with the higher grades of the calling, should remember that some movement in the interest of the unhappy girls themselves is necessary. In the low brothels in London the system is a most cruel one. A girl is at first well treated, and encouraged to fall into debt to her employer. As soon as she is fairly involved, she is a slave; there is no relief till she can make no more money, when she is cast out. Surely something should be done to save her. Possibly it might be well to try the plan of recognising no debts from a girl to the procuress or brothel-keeper, and to also devise means for at once giving her the means of release from her life if she desires it. Also, if such houses must exist—and who can venture to hope they will not?—they may at least be made less indecent, quieter, and safer from theft and even murder. At present the system, as it exists, is a gigantic scandal to Christianity, and Jeannel's singular work has shown how curious a parallel there is between modern prostitution and that which dimmed the splendour, and perhaps hastened the fall, of Imperial and Pagan Rome. Eighteen centuries after the death of Christ, are we still at such a point?

[2] The military stations named in the *Contagious Diseases Act* in 1866 were Portsmouth, Plymouth, and Devonport; Woolwich, Chatham, and Sheerness; Aldershot, Windsor, Colchester, Shorncliffe, Curragh, Cork, and Queenstown. Others were afterwards added. Adjoining parishes were in many cases included.

[3] For the statistics of this question, see *Army Medical Report* for 1880, vol. xxii. pp. 12–17 and 368–371.

It must be remembered that gonorrhœa was not touched by the Act, for want of hospital accommodation, so that the nearly equal amount of gonorrhœa of the two classes shows that the enormous lessening of primary venereal sore in the controlled stations was owing to a real diminution of syphilis, and not to lessened frequency of intercourse. This is proved again by the following figures given by Dr Balfour.

In 1864, the year before the Act came into operation, the average admissions at all the stations from primary venereal sore were 108·6 per 1000. In 1872, at the uncontrolled stations, the number was still higher, being 123·2, so that syphilis had not declined in the uncontrolled stations. But in the controlled stations in 1872 the admissions were only 53·3. Therefore, the gain to the State in the controlled stations was (108·9–53·3) 55 admissions less per 1000 of strength; and in a mean strength of 50,000 men the State was saved the cost of 2750 cases of primary venereal sore in that year, and the men were saved the enormous injury to their health, which would otherwise have resulted.

Let the facts be put in another form. Taking the first seven years that the Acts were in operation (before the introduction of the stoppage regulation in 1873), viz., 1865–72 (though in the early years the operation was partial and imperfect), we have the following figures :—

Admission per 1000 of Strength 1865–72 inclusive.

	Primary Sores.	Gonorrhœa.
All stations not under the Act (mean strength 32,528 men), . . .	103·1	111·7
Stations under the Act (mean strength 30,765 men), ...	62·8	115·0

There was therefore a practical identity in gonorrhœal admissions, but the annual admissions for primary venereal sores were reduced in the controlled stations by 40·3 per 1000. In the eight years the State was therefore saved very nearly 10,000 cases of syphilis; and supposing each demanded twenty days of treatment (which is moderate), 200,000 days of sickness have been saved in eight years.

Such, then, was the operation of the Act under many disadvantages, but this was not its only beneficial effect.

The Act at the large stations did great good in some other directions, especially as regards the women. Many women were reclaimed; the horrible juvenile prostitution almost ceased, and comparative decency was taught in the hospitals.

Taking the last three years of the Acts (1880–2) we have :—

	Primary Sores.	Gonorrhœa.
All stations not under the Act (mean strength 43,372), ...	122	110
Stations under the Act (mean strength 41,779), ...	76	100

Lastly, let us take the series of years during the operation of the Acts (19), viz., 1864–82 inclusive (for the operation of the stoppage order in 1873–9 was the same for all).

[1] Data are not given in the A. M. D. Reports to enable *all* the stations not under the Act to be considered for the whole of these years.

	Primary Sores.	Gonorrhœa.
14 stations not under the Acts (mean strength 18,486),[1] .	116	106
14 stations under the Acts (mean strength 45,468), ...	61	95
Difference, ...	55	11
or, ...	90 per cent.	12 per cent.

With these we may compare the years 1883 and 1884, in the former of which the Acts were practically abrogated :—

		Primary Sores.
14 stations not under the Acts, ...	1883	188
” ” ”	1884	160
14 stations formerly under the Act, . . .	1883	110
” ” ” ” . . .	1884	138

So that things are rapidly falling back into their old evil condition.

One consequence of the Contagious Diseases Act was to make public the most frightful state of things among the women of our garrison towns. The vivid picture of the Chatham prostitute's life drawn by Mr Berkeley Hill[1] was no exaggeration. Reports from the Lock hospitals at other places would, if published, have borne out all Mr Hill alleged. Shocking as these disclosures are, and mortifying as they may be to our national pride, it is by far the best plan to have them made. An evil like this must not be treated in the shade; it will never be overcome till the public know its proportions; the deadly mists which cling round and poison the very basis of society can be dispersed only when the healing light of the sun falls on them. It was encouraging to learn that the effect of the Act had been greatly to improve the manners and habits of the women—to impose some restraint on them, and to restore to them something that, in comparison with their former life, may be called decency; and the regret is proportionately great that all this good has been thrown away.

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[1] *British Medical Journal*, 1867.

CHAPTER XIX.

STATISTICS.

An accurate basis of facts, derived from a sufficient amount of experience, and tabulated with the proper precision, lies at the very foundation of hygiene, as of all exact sciences. Army surgeons have already contributed much important statistical evidence as to the amount and prevalence of different diseases, and it is evident that no other body of medical practitioners possess such opportunities of collecting, with accuracy, facts of this kind, both among their own nations and others. As they have to make many statistical returns, it seems desirable to make a few brief remarks on some elementary points of statistics, which are necessary to secure the requisite accuracy in collecting and arranging facts. But it is, of course, impossible to enter into the mathematical consideration of this subject, for a separate treatise would be required to do justice to it.[1]

SECTION I.

A FEW ELEMENTARY POINTS CONNECTED WITH GENERAL STATISTICS.

1. The elements of statistical inquiries are individual facts, or so-called numerical units, which, having to be put together or classed, must have precise, definite, and constant characters. For example, if a number of cases of a certain disease are to be assembled in one group with a definite signification, it is indispensable that each of these cases should be what it purports to be, an unit not only of a definite character, but of the same character as the other units. In other words, an accurate diagnosis of the disease is essential, or statistical analysis can only produce error. If the numerical units are not precise and comparable, it is better not to use them. A great responsibility rests on those who send in inaccurate statistical tables of disease; for it must be remembered that the statist does not attempt to determine if his units are correct; he simply accepts them, and it is only if the results he brings out are different from prior results that he begins to suspect inaccuracy.[2]

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[1] It is much to be regretted that we have as yet no really good work on the principles and methods of Statistics in the English language; such a work is a desideratum. The selected works of Dr Farr, edited for the Sanitary Institute of Great Britain by Mr Noel Humphreys (1885), may be referred to as giving many admirable examples of what statistics ought to be.

[2] It is in vain to conceal the fact that many persons look at tables of diseases collected indiscriminately as worse than useless, from errors in diagnosis. Even in the army returns, which are all furnished by qualified practitioners, there is reason to doubt the correctness of the earlier tables especially. But it is believed that the army returns of diseases are now gaining in accuracy, and it cannot be too strongly urged on medical officers that perfect accuracy in diagnosis is a duty of the highest kind. It is much better to have a large heading of undetermined diseases than, when in doubt, to put a case of disease under a heading to which it has no unequivocal pretensions. It is greatly to be regretted that, from the abridged form in which they are now published, much valuable information is now no longer obtainable from the *Army Medical Reports*.

2. These items or numerical units being furnished to the calculator, are by him arranged into groups; that is to say, he contemplates the apparently homogeneous units in another light, by selecting some characteristic which is not common to all of them, and so divides them into groups. To take the most simple case:—A certain number of children are born in a year to a given population. The children are the numerical units. They can then be separated into groups by the dividing character of sex, and then into other groups by the dividing character of "born alive," or "still born," &c.

Or, a number of cases of sickness being given, these numerical units (all agreeing in this one point, that health is lost) are divided into groups by diseases, &c.; these groups, again, are divided into others by the character of age, &c.; and in this way the original large group is analysed, and separated into minor parts.

This group-building seems simple, but to group properly complex facts, so as to analyse them, and to bring out all the possible inferences, can only be done by the most subtle and logical minds. The dividing character must be so definite as to leave no doubt into which group an unit shall fall; it must be precise enough to prevent the possibility of an unit being in two groups at the same time. This rule is of the utmost importance, and many examples could be pointed out of error from inattention to it.

Having decided on the groups, their numerical relations are then expressed in figures; for example:—

3. In order to express the relation of the smaller groups to the gross number of individual facts or units, a constant numerical standard must be selected, else comparison between groups of unequal numbers cannot be made. The standard universally adopted in medical statistics is to state this relation as a percentage, or some multiple of a percentage. So much per cent., or per 1000, or per 10,000, is the standard. This is got simply by multiplying the number of units in the smaller groups by 100, and dividing by the total number of units. Thus, let us say there occur 362 cases of pneumonia; this is divided into two groups of recovered or died, say 343 recoveries and 19 deaths; and their relation may be expressed in one of two ways, viz., either by the relation of the deaths to the total number of cases, which will be—

$$\frac{19 \times 100}{362} = 5{\cdot}25 \text{ per cent.}$$

of mortality; or by the relation of the deaths to recoveries, viz.—

$$\frac{19 \times 100}{343} = 5{\cdot}54 \text{ per cent.}$$

4. Having established that in a certain number of cases, divided into groups, the number in each group bears a certain proportion to the whole, how far are we justified in concluding that the same proportions will be repeated in future cases? This will chiefly depend on the number of the cases. If the number of cases from which one proportion has been taken is small, we can have no confidence that the same proportion will be repeated in future cases. If the number is large, there is a greater probability that the proportion in succeeding numbers of equal magnitude will be the same. The result obtained even from a very large number is, however, only an approximation to the truth, and the degree in which it approaches the truth can be obtained by calculation. The following rule is given by Poisson for calculating the limits of error, or, in other words, the degree of approximation to the truth:—

Let μ be the total number of cases recorded,
m be the number in one group,
n be the number in the other,

So that $m+n=\mu$.

The proportion of each group to the whole will be respectively $\frac{m}{\mu}$ and $\frac{n}{\mu}$, but these proportions will vary within certain limits in succeeding instances. The extent of variation will be within the proportions represented by

$$\frac{m}{\mu}+2\sqrt{\frac{2.\,m.\,n}{\mu^3}}$$

and[1]

$$\frac{m}{\mu}-2\sqrt{\frac{2.\,m.\,n}{\mu^3}}$$

It will be obvious that the larger the value of μ the less will be the value of $\sqrt{\frac{2.\,m.\,n}{\mu^3}}$, and consequently the less will be the limits of error in the simple proportion $\frac{m}{\mu}$.

An example will show how this rule is worked. The following is given by Gavarret:[2]—

Louis, in his work on *Typhoid Fever*, endeavours to determine the effect of remedies, and gives 140 cases, with 52 deaths and 88 recoveries. What is the mortality per cent., and how near is it to the true proportion?

$m = 52$ = number of deaths,
$n = 88$ = number of recoveries,
$\mu = 140$ = total number of cases,

i.e., 37 deaths in 100 cases, or more precisely 37,143 deaths in 100,000 cases. How near is this ratio to the truth? The possible error is as follows—the second half of the formula, viz.:—

$$2\sqrt{\frac{2.\,m.\,n}{\mu^3}}$$

will be

$$2\sqrt{\frac{2\times 52\times 88}{(140)^3}}=0{\cdot}11550 \text{ to unity.}$$

(Or 11,550 in 100,000.)

The mortality being 37·143 per cent., or 37,143 deaths in 100,000 cases, in these cases, it may be in other 140 cases either

$$37{,}143+11{,}550=48{\cdot}693 \text{ per cent.}$$

or

$$37{,}143-11{,}550=25{\cdot}593 \quad \text{,,}$$

In other words, in successive 140 cases the mortality will range from 49 per

[1] This is sometimes stated thus:—

$$\frac{p}{q}\times\sqrt{\frac{8p(q-p)}{q^3}}$$

when q = total number of events,
and p = total number of events in any particular direction.

[2] *Statistique Médicale*, 1840, p. 284.

cent. (nearly) to 26 per cent. (nearly), so that Louis' numbers are far too few to give even an approximation to the true mean.[1]

5. There being a number of facts, each of which can be expressed by a numerical value, an average or mean number is obtained by adding all the numerical values, and dividing by the number of facts.[2] This gives the common or *arithmetical* mean, which can be shown mathematically to be the nearest to the truth in physical inquiries. Its degree of approximation may be determined by working out the probable error,[3] the smaller the latitude of error the more trustworthy the series from which the mean number is drawn. To compare two or more similar groups together, the probable error of each must be ascertained, the relative values being as the reciprocals of the squares of the probable errors; that is $\frac{1}{(pe)^2}$, where (pe) is the probable error. Thus if we have two groups, A and B, A having a probable error of 10 per cent. and B one of 2 per cent., the value of A will be $\frac{1}{10^2}=\frac{1}{100}$, and the value of B will be $\frac{1}{2^2}=\frac{1}{4}$; the reciprocals will be respectively 100 and 4, or the group B will have a value 25 times as great as A.

The relative values of two or more series are also as the square roots of the numbers of units of observation. So also, by increasing the number of observations in any inquiry, the value (or accuracy) increases as the square root of the number.

Thus a group of 10 observations is to a group of 100 as $\sqrt{10}$ to $\sqrt{100}$, or as 3·16 to 10.

In many cases the method by successive means is very useful. This consists in taking the mean of the mean numbers successively derived from a constantly repeated series of events (say the mortality to a given population yearly). Supposing, for example, the annual mortality in England to be, in successive years, 22, 23, 21, 26, 23, 21, 22, 28, 22, 21, per 1000 living, the successive means would be—

$$\frac{22+23}{2} \qquad \frac{22+23+21}{3} \qquad \frac{22+23+21+26}{4}$$

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[1] The latitude of error being so large with such a comparatively high number of observations, it may be easily conceived what absurd results will be arrived at when only two or three cases are depended upon to support a hypothesis. Suppose three cases, two of which are fatal, the range will then be between + 145 per cent. and − 11 per cent., that is, the mortality may be 45 per cent. more than the cases, or 11 per cent. less than nothing!

[2] The *arithmetical* mean is used in medical inquiries; but there are, in addition, the *geometrical, harmonic,* and *quadratic* means. For an account of these, and for many rules, reference may be made to Dr Bond's translation of Professor Radicke's Essay, *New Sydenham Society Publ.*, vol. xi.

[3] To find the *mean error*:—1. Find the *mean* of the series of observations; then find the *mean* of all the observations *above* the mean, and subtract the mean from it, this gives the mean error in excess. 2. Find the *mean* of all the observations *below* the mean, and subtract it from the mean, this gives the mean error in deficiency. Add the two quantities, neglecting *plus* and *minus* signs, and take the half, this is the *mean error*.

To find the *error of mean square*:—Square each of the observations and add them together, subtract from this sum the square of the mean, multiplied by the number of observations, then, calling this remainder (S), and the number of observations (n), we have:—

$$\text{Error of mean square, . . .}\begin{cases}\text{Of a single measure, . .} & \sqrt{\dfrac{S}{n-1}},\\[2ex] \text{Of the result, ...} & \sqrt{\dfrac{S}{n(n-1)}}.\end{cases}$$

The *probable error* is obtained by taking two-thirds (nearly) of the mean error or error of mean square, the actual ratio being 1 : 0·6745.

and so on, until the numbers are so great as to give every time the same result. It is useful to calculate the successive means in both the direct and inverse order, viz., from first to last, and then from last to first, *i.e.*, putting the two last together, then the three last, &c., so as to see if the variation was greater at the end of a series than at the beginning. The degree of uncertainty is then the mean variation between the successive means.

A plan almost the same as this has been used: a certain number of facts being recorded, the sum is divided into two, three, or more parts, and it is then seen whether the results drawn from the lesser groups agree with that drawn from the larger group and with each other. If there is any great difference of results, the numbers of the lesser groups are not sufficient. In the instance given above, the mean of the ten years is 22·9; the mean of the first three years is 22; of the second three years is 22·33; of the third three years is 24. The term of three years is therefore far too short to allow a safe conclusion to be drawn. The mean of five years again is 23, and of eight years is 22·8, numbers which are much nearer each other and to the mean of the whole ten years.

The application of averages when obtained is of great importance, but there is one usual error. The results obtained from an average (that is, from the mean result obtained from a number of units, not one of which perhaps is the same as the mean result, but either above or below it) can never be applied to a particular case. On either side the average there is always, as before shown, a range the value of which may be obtained by Poisson's rule, or by the determination of the mean error, and the particular case may be at either end of the range. The use of the average is to apply it to an aggregate of facts. Then, supposing it to be founded on a sufficient number of cases, it will approximate proportionately to exactitude.

6. In addition to averages, it is always desirable to note extreme values, that is, the two ends of the scale of which the average is the middle. To use Dr Guy's pointed expression, "averages are numerical expressions of probabilities; extreme values are expressions of possibilities." [1] In taking too great note of mean quantities, we may forget how great a range there may be above and below them, and it is by reminding us constantly of this that Poisson's rule and the rule for *mean error* are so useful.[2]

7. Statistical results are now frequently expressed by graphic representations, a certain space drawn to scale representing a number. The most simple plan is that of intersecting horizontal and vertical lines.

Two lines, one horizontal (axis of the *abscissæ*) and the other vertical (axis of the *ordinates*), form two sides of a square, and are then divided into segments, drawn to scale—vertical and horizontal lines are then let fall on the points marked; the axis of the ordinates representing, for example, a certain time, and the axis of the abscissæ representing the number of events occurring at any time. A line drawn through the points of intersection of these two quantities forms a graphic representation of their relation to each other, and the surface thus cut can be also measured and expressed in area if required, or the space can be plotted out in various ways, in columns, pyramids, &c. In the same way circles cutting radii at distances from the centre drawn to scale are very useful; the circles marking time (in the example chosen), and

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[1] *Cyclopædia of Anatomy and Physiology*, art. "Statistics."

[2] In a good (that is a trustworthy) series, the extremes on the two sides of the mean will balance each other, the numbers being distributed according to the coefficients of a binomial, whose exponent is the number of possible events in the series (see Quetelet, *On Probabilities*; Airy, *On the Theory of Errors of Observation*; Merriman, *Theory of Least Squares*; F. de Chaumont, *Lectures on State Medicine*). See table in Appendix E.

the radii events, or the reverse. Such graphic representations are most useful, and allow the mind to seize more easily than by rows of figures the connection between two conditions and events.

Generally speaking, it may be said that the amounts of sickness and mortality in different bodies of men, or in the same body of men at successive periods, show such wide variations, that the mean error is always very great, and it requires a very large number of cases, and an extended period, to deduce a probable true mean. For this reason it is necessary to be cautious in apportioning blame or credit to persons, or to special modes of treatment, unless the numbers are very large and accordant.[1] The circumstances influencing the result are, in fact, very numerous, and the proper estimation of a numerical result is only possible when it is considered in reference to the circumstances under which it occurs.

The most important statistical inquiries applied to health are—

1. *Births to Population.*—To obtain all these elementary facts, an accurate census and proper registration are required. It is only within recent years that the most civilised nations have commenced these inquiries.

2. *Relative Number of Live and Still-Born, of Premature and Full-Grown, Children.*

3. *Number of Children Dying in the First Year, with Sub-Groups of Sex and Months.*—There are two great periods of mortality in the first year, viz., in the first week, and at the time of weaning, about the seventh month.

4. *Amount of Sickness to Population.*

(*a*) Number constantly sick, grouped according to sex, age, occupation, and diseases.

(*b*) Average duration of sickness, &c.

5. *Amount of Yearly Mortality in a Population, or Deaths to Population.*—The deaths are generally expressed as so many deaths to 1000 or 10,000 living; but the deaths can be calculated in relation not only to the number living at the end of the time, but to that number *plus* a certain addition to be made on account of those persons who lived during part of the time, but died before its close. But the difference is not material. Grouped according to sex, age, &c.

6. *Mean Age at Death of a Population is the Sum of the Ages at Death divided by the Deaths.*—The mean age at death expresses, of course, the expectation of life at birth, or the mean lifetime. It is no very good test of the health of a people, as a great infant mortality may reduce the age, though the health of the adults may be extremely good. The mean age at death in England is about 40 years. Farr has shown that it is nearly equivalent to the reciprocal of the death-rate *minus* one-third of the difference between the reciprocal of the death-rate and that of the birth-rate; or two-thirds the reciprocal of death-rate *plus* one-third that of the birth-rate.[2]

7. *Mean Duration of Life* (*vie moyenne*).—This is the expectation of life at birth; at any other age than birth, it is the expectation of life at that age (as taken from a life-table) added to the age. It is no good test of sanitary condition or health.

8. *Probable Duration of Life* (*vie probable;* probable lifetime) is the age at which a given number of children born into the world at the same time will be reduced one-half.

9. *Expectation of Life, or Mean Future or After Lifetime.*—This is the

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[1] See note on page 482.

[2] Suppose the death-rate to be 1 in 46, and the birth-rate 1 in 29 (about the existing rates in England), we have $\frac{46\times2}{3}=30\cdot7+\frac{29}{3}=9\cdot7=40\cdot4$=mean age at death in England.

true test of the health of a people. It is the average length of time a person of any age may be expected to live; and in order to construct it, we must know the number of the living, their ages, the number of deaths and the ages at death, and the other changes in the population caused by births, emigration, immigration, &c. It does not, of course, follow that any particular person will live the time given in such a table; he may die before or after the period, but taking a large number of cases, the average is then found to apply. Life-tables show at a glance the expectation of life at any age.

England. [1]

Age.	Males.	Females.	Age.	Males.	Females.	Age.	Males.	Females.
0	39·91	41·85	10	47·05	47·67	70	8·45	9·02
1	46·65	47·31	20	39·48	40·29	80	4·93	5·26
2	48·83	49·40	30	32·76	33·81	90	2·84	3·01
3	49·61	50·20	40	26·06	27·34	95	2·17	2·29
4	49·81	50·43	50	19·54	20·75	100	1·68	1·76
5	49·71	50·33	60	13·53	14·34			

After the first year the chances of living increase up to the fourth year; the fifth year is nearly as good, and then the chances of life lessen, but at first slowly, and then more rapidly; from 5 to 40 years of age the expectation of life lessens in the ratio of from $2\frac{1}{2}$ to $3\frac{1}{2}$ or $3\frac{3}{4}$ years for each quinquennial period.

For Army Statistics, see Book II.

[1] Abridged from Dr Farr's Life Tables. Some interesting information will be found in *Statistics of Families*, by C. Ansell, jun., 1874.

BOOK II.

THE SERVICE OF THE SOLDIER.[1]

It is now necessary to consider a little more particularly the nature of the service of the soldier, and the influence it has on him. A recruit entering the army from civil life comes under new conditions, which will require to be shortly enumerated.

CHAPTER I.

THE RECRUIT.

In the English army, young men are now enlisted at nineteen years of age,[2] unless they are intended for drummers. They must be of a certain height, which is fixed by regulation from time to time, according to the particular arm, and to the demands of the service. There must also be a special girth of the chest, which is in proportion to the age and height.

In time of war the measurements are reduced according to the demand for men; and even in time of peace the necessary height of the infantry recruit is varied. At present it is 64 inches.[3] Before the enlistment is completed, the recruit is examined by a medical officer, and then by the surgeon-major of the recruiting district, according to a scheme laid down in the *Medical Regulations*.[4] The scheme is a very good one, and aims at investigating, as far as can be done, the mental condition; the senses; the general formation of the body, and especially of the chest; the condition of the joints; the state of the feet; the absence of hernia, varicocele, piles, &c.; and the condition or physical examination of the heart, lungs, and abdominal organs generally.[5] A certain minimum girth of chest according to the height is required.[6]

After joining his regiment he is again examined, and may be rejected if

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[1] Medical officers entering the army will find a great deal of useful sanitary information and details of duty bearing on health in Viscount Wolseley's *Soldiers' Pocket Book for Field Service*, 5th edit., 1886.

[2] In reality, they sometimes enlist under this age.

[3] General Order, No. 81, July 1881.

For a full account of the system of recruiting, the mode of examination, and much useful information on disabilities, see a paper by Dr Crawford in the *Army Medical Report* for 1862; *Blue Book*, 1864. See *Medical Regulations* (1885), part 5, section ii.

[5] As the *Medical Regulations* are in the hands of all medical officers, it is unnecessary to go into more detail on this point. Sir Thomas Longmore uses in the Army Medical School a set form of examination (*Instructions on the Examination of Recruits*, Southampton, 1882), which renders it almost impossible that any point should be overlooked.

[6] At present, 34 inches for 64 to 70 in height; 35 inches if above 70 in height.

any defect is discovered. Rejections may take place, then, either at the primary or secondary inspection.

The trades of the men furnishing the recruits vary greatly from year to year.

The total number of rejections, either at once or after re-examination by a second medical officer, on various grounds, of men brought by the recruiting sergeant to the medical officer, varies somewhat from year to year. In 1884 the rejections were 27,888, or nearly 417 per 1000.

About two-fifths of the rejections arise from causes connected with general bad health or feeble constitution, and one-fifth from causes affecting the marching powers of the men (Balfour). The remainder are rejected for being under height, weight, or chest measurement.

In the French army the height was fixed in 1860 at 69 inches (1·76 metres) for the carabiniers, and 61½ inches (1·56 metres) for the infantry of the line.

In 1872 the minimum for the cuirassiers was reduced to $1^{m}·70$ (67 inches) without any fixed maximum.

In 1868 the minimum for the line was reduced to $1^{m}·55$ (61 inches), and still further in 1872 to $1^{m}·54$ (60½ inches). Now, however, there is practically no minimum, for men who are below $1^{m}·54$ are directed to be enrolled in the Auxiliary Army.[1]

The rejections in the French conscription include men rejected for insufficient height, as well as reasons of health.[2]

After the recruit has been enlisted and approved, he joins his depôt or his regiment; receives his kit, which he subsequently in part keeps up at his own cost; and is put on the soldier's rations. He enters at once on his drill, which occupies from 3½ to 4½ hours daily. Wherever gymnasia are established, he goes through a two months' course of gymnastic training for one hour every day. He then goes to rifle drill, which lasts about six weeks, and then joins the ranks. After the rifle drill, he has another month's gymnastic training, and is then supposed to be a finished soldier.

Such being the system, it will be desirable to consider certain points.

1. *The Age of the Recruit.*—Strong opinions have been expressed by Ballingall (English army), Lévy (French army), Hammond (American army), and other army surgeons that the age of 17 or 18 is too low—that the youngest recruit should be 20 or 21 years of age.

This opinion is based both on actual experience of the effect produced on boys of 17 to 20 when exposed to the hardships of war, or even to heavy duty in time of peace, and on a physiological consideration of the extreme immaturity of the body at 18 years of age.

With regard to the first point, there is no doubt that to send young lads of 18 to 20 into the field is not only a lamentable waste of material, but is positive cruelty. At that age such soldiers, as Napoleon said, merely strew the roadside and fill the hospitals. The most effective armies have been those in which the youngest soldiers have been 22 years of age.

With regard to the second, it is also certain that at 18 the muscles and bones are very immature, and, in fact, it is not till 25 years of age, or even later, that the epiphyses of the bones have united, and that the muscles have attained their full growth.[3]

The epiphyses of the transverse and spinous processes of the vertebræ hardly commence to ossify before 16 years of age, and it is not till after 20

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[1] Morache, *Traité d'Hygiène Militaire*, 2nd ed., 1886.
[2] Sistach, *Recueil de Mém. Mil.*, Nov. 1861, p. 353.
[3] See *Growth of the Recruit and Young Soldier*, by Sir William Aitken, M.D., F.R.S., 2nd ed., 1887.

years that the two thin circular plates form on the body of the vertebræ. The whole process is not completed till close on the 30th year. The consolidation of the sacrum only commences at the 18th year, and is completed from the 25th to the 30th year. The fourth and third bones of the sternum are only united between the 20th and 25th years, and the second is not united to the third bone before the 35th year. The epiphyses of the ribs commence to grow between the 16th and the 20th years, and are completed by the 25th year. The epiphyses of the scapula join between the ages of 22 and 25. The epiphysis of the clavicle begins to form between the 18th and 20th years. The internal condyle of the humerus unites at 18, but the upper epiphysis does not join till the 20th year. The epiphyses of the radius and ulna, the femur, the tibia, and fibula, are all unjoined at 18 years, and are not completely joined till 25 years. The epiphyses of the pelvic bones (viz., crest of ilium, spine, and tuberosity of the ischium) begin to form at puberty, and are completed by the 25th year.[1]

That the muscles are equally immature is just as certain; they grow in size and strength in proportion to the bones.

These facts show how wrong it is to expect any great and long-continued exercise of energy from men so young as 18 and 20, and what will be the inevitable consequences of taxing them beyond their strength.

Are we, then, to conclude that the soldier should not be enlisted before 20?

If the State will recognise the immaturity of the recruit of 19 years of age, and will proportion his training and his work to his growth, and will abstain from considering him fit for the heavy duties of peace and for the emergencies of war till he is at least 20 years of age, then it would seem that there is not only no loss, but a great gain, by enlisting men early. At that most critical period of life the recruits can be brought under judicious training, can have precisely the amount of exercise and the kind of diet best fitted for them, and thus in two years be more fully developed, and be made more efficient, than if they had been left in civil life.

2. *The Height and Weight of the Recruit.*—The desire of almost all military officers is to get tall men. The most favoured regiments, especially the cavalry, get the tallest men. It has been recommended both that shorter men should be generally taken, and that the infantry should have the tallest men. The last point is one for military men to determine, and must be decided by considerations of the respective modes of action of cavalry and infantry.

The first point is entirely physiological, and opens a difficult question.

What is the height, at 19 years of age, which is attended with the greatest amount of health, strength, and endurance, or is it possible to fix such a standard?

Tables of average height and weight have been compiled by Quetelet, and much used, and lately somewhat similar tables have been framed by Danson, Boyd, Liharzik,[2] and Roberts.

With regard to all of these it may be said that the observations (however numerous) are yet too few for such a large question, and that the influence of race has been too little regarded.

Boyd gives the height at 18 years at 60·4 inches, and at 25 years at 67 inches, and Liharzik at the same ages gives 64·17 and 68·9 inches. The

[1] See Aitken's *Growth of the Recruit*, 2nd ed., and Quain's *Anatomy*, for still further details.

[2] Liharzik's numbers profess to be based on a law induced from great numbers of measurements in different animals.

English Army Returns (1860–67) give the heights of the recruits, but it must be understood that we cannot deduce the mean height of the population from these figures, as the shorter men are not taken as recruits.

Although the numbers are not very accordant, we may perhaps assume that at 19 the average height will be something near 65 inches, and the average weight 125 ℔.

The best rule to guide us is that given by Sir William Aitken, viz., to take into consideration the three points of age, height, and weight, and if either in weight or height, or both together, there is any great divergence from the mean, then something wrong will probably be found. But as long as weight and height are in accord, the taller and heavier the man the better, as a rule. The weight in pounds ought to be about *twice* the height in inches.[1]

One point is, however, quite clear. When the height is much below the mean, the bodily development generally is bad. Hammond states that in the American War, men of less than 5 feet broke down by a few weeks' campaigning, while men of 5 feet stood the work well. Probably 63 inches at 19 years of age, and 120 ℔ weight, should be a minimum, even in times of the greatest pressure. So also a very great height at 19 years of age is objectionable, and anything over 68 inches at that age should be looked on with great suspicion. As a rule, also, adult men of middle size (67 to 69 inches) appear to bear hard work better than taller men.[2]

3. *The Physical Training of the Recruit.*—A great improvement has been introduced by the order that each recruit shall have three months' gymnastic training. If properly done, this should have a most beneficial effect. The medical officer has power to continue this if necessary, and care should be taken to use this power.

4. *The Mental Training.*—Since the introduction of rifle practice, the trade of the soldier has become much more interesting to him; he is now taught scientifically how to manage his arm, and learns to take interest in his shooting. It would be most desirable to give him some knowledge of the Military Art and of the object of the manœuvres he goes through. A military literature fitted for the private soldier is still wanting. It is also very important to train him for the field, and to teach him to perform for himself all the offices which in time of war he will have to do—not merely trench work, but hutting, cooking, washing and mending his clothes, as in time of war. It is too late, at the commencement of a campaign, to begin these necessary parts of a soldier's education; they should form part of his training as a recruit; and if he is excused guard and other duties during his first year there would be ample time.

Great attention is now being directed to the importance of soldiers keeping up their trades, or learning some trade if they have none. Such a system occupies men, makes them contented, keeps them from dissipation, and opens a career for them when they leave the army. Instead of interfering with their military training, it can be made to subserve it, and

[1] In France the weight is reckoned at the rate of 700 to 725 grammes for each centimetre of chest-girth: this is equal to 4 ℔ for each inch in English measurement. If these two rules were combined we might state it thus: the weight should be one-third more (in ℔) than the sum of the height and chest-girth (in inches). Thus a man of 64 in. height and 34 in. chest-girth should have 131 ℔ weight; or if he is 70 inches in height and 35 round the chest, then he should weigh not less than 140 ℔. In this latter case the same result exactly is obtained by doubling the height.

[2] For some useful information on these points, see Morache, *op. cit.*, Roth and Lex, *op. cit.*, and Auguste Jansen, *Études sur la taille, le périmètre de la poitrine et le poids des recrues*, extrait des *Archives Médicales Belges*, 1877; also *Étude d'Anthropométrie Médicale au point de vue de l'Aptitude au service Militaire*, by the same author, Bruxelles, 1882.

possibly might be found to be advantageous to the State, even in a pecuniary point of view. The recruit then would have to keep up or learn his trade.

5. *The Moral Training.*—The recruit, on entering the army, is brought under moral influences of a strong kind. A discipline always rigorous, and sometimes severe, produces often a ready obedience and a submission of character, and, when not carried too far, greatly improves him. At the same time, independence is preserved by the knowledge which the soldier has of his rights and privileges, and the result is a manly, conscientious, and fine character. But occasionally, a too sensitive nature on the part of the recruit, or a discipline too harsh or capricious on the part of his officers, produces very different results, and the soldier becomes cunning, artful, and false, or morose and malicious. The two characters used to be often seen well marked in old soldiers, and no contrast could be greater than between the two. A heavy responsibility rests, then, with the officers of the army who have power thus to influence, for good or evil, natures like their own.

The influence of companionship is also brought to bear on the recruit, and is fraught with both good and evil. The latter probably predominates, though there are many excellent, high-minded, and religious men in the army. Indeed, in some regiments the proportion of steady religious men is perhaps beyond the number in the analogous class in civil life. But if the influences be for bad, the recruit soon learns some questionable habits and some vices.

Thus he almost invariably learns to smoke, if he has not acquired this habit before. It is indeed remarkable what a habit smoking tobacco is in every army of Europe; it seems to have become a necessity with the men, and arises probably from the amount of spare time the soldier has, which he does not know what to do with. A recruit, on joining, finds all his comrades smoking, and is driven into the habit.

The discussion on the effects of tobacco does not seem to have led to any clear conclusions. The immoderate use brings many evils to digestion and circulation especially. But no great evils appear to result from the *moderate* use, though no good can be traced to it. In moderation it has not been proved to lessen appetite, to encourage drinking, or to destroy procreative power. But, on the other hand, it probably lessens bodily, and perhaps even mental activity. It is certainly remarkable how uniformly the best trainers prohibit its use, and men of the highest physical vigour are seldom great, and often are not even moderate, smokers. As it is of no use, and indeed injurious, by bringing men under the thraldom of a habit, it seems very desirable to discourage it. But in the army it seems useless to fight against this custom, nor is it indeed one which is sufficiently injurious to be seriously combated, except for one reason. In time of war the soldier often cannot obtain tobacco, and he then suffers seriously from the deprivation. The soldier should have no habits which he may be compelled to lay aside, and which it would pain him to omit.

A much more serious matter is the vice of drinking, which many recruits are almost forced into, in spite of themselves. The discipline of the army represses much open drunkenness, though there is enough of this, but it cannot prevent, it even aids, covert drinking up to the very edge of the law. Formerly, a most lamentable canteen custom made almost every man a drunkard, and a young boy just enlisted soon learned to take his morning dram, a habit which, in civil life, would mark only the matured drunkard. Now, happily, spirits are not sold in the canteens, and no regulation thrusts raw spirits down a man's throat. Drinking is, however, still the worst vice in the army, and that which strikes most of all at the efficiency of the

soldier. Great efforts have been, however, made by the military authorities to check this vice, and there is little doubt that the army is gradually becoming more temperate.

Another vice is almost as certainly contracted as smoking by the recruit. Probably before enlistment he has led no very pure life, but when he enters the army he is almost sure to find his moral tone higher than that of some of his new associates. A regiment, in fact, is composed of young men with few scruples and small restraints. Prevented from marriage, and often tempted by low prostitutes, it is no wonder if, to the extent of his means, the soldier indulges in promiscuous sexual intercourse. He does this, in fact, to excess, and the young recruit is led at once into similar habits. That many recruits are most seriously injured by this habit, even if they neither contract syphilis nor gonorrhœa, is certain.

It has also been supposed that solitary vice is particularly rife in armies. There does not seem to be any evidence on this point.

6. *The Amount of Sickness and Mortality suffered by the Recruit during the First Six Months and Year of Service.*—This is an extremely important matter, but at present we are not able to answer the question for the English army.

In the French army [1] the amount of sickness among soldiers under one year of service is more than one-third greater than among the army generally; this is partly caused by slight injuries, though not solely, for the admissions to hospital are nearly one-fourth more among them than in the army at large.

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[1] *Statistique Médicale de l'Armée.*

CHAPTER II.

THE CONDITIONS UNDER WHICH THE SOLDIER IS PLACED.

These conditions are extremely various, as the soldier serves in so many stations, but the chief points common to all can be passed in review.

The water and air supplies have been already sufficiently noticed, and the conditions now to be noticed under which the soldier is placed are *barracks*, *huts*, *tents*, and *encampments;* the *food*, *clothing*, and *work*.

SECTION I.

BARRACKS.

Barracks have been in our army, and in many armies of Europe still are, a fertile source of illness and loss of service. At all times the greatest care is necessary to counteract the injurious effects of compressing a number of persons into a restricted space. In the case of soldiers the compression has been extreme; but the counteracting care has been wanting. It is not much more than sixty years since, in the West Indies, the men slept in hammocks touching each other, only 23 inches of lateral space being allowed for each man. At the same time, in England, the men slept in beds with two tiers, like the berths in a ship; and not infrequently, each bed held four men. When it is added, that neither in the West Indies nor in the home service was such a thing as an opening for ventilation ever thought of, the state of the air can be imagined.

The means of removal of excreta were, even in our own days, of the rudest description, both at home and in many colonies; and from this cause alone there is no doubt that the great military nations have suffered a loss of men which, if expressed in money, would have been sufficient to rebuild and purify every barrack they possess. To these two causes must be attributed the great loss suffered by our troops in former years from phthisis and enteric fever.

Sub-Section I.—Barracks on Home Service.[1]

The imperfection of the English barracks was owing to two causes—first, a great disregard or ignorance of the laws of health; and, secondly, an indisposition on the part of Parliament to vote sums of money for a standing army. At the close of the last, and at the commencement of the present century, the Whig party especially opposed every grant which Mr Pitt

[1] Army medical officers are referred to an admirable paper by Surgeon-General Dr Massy, C.B., on the Construction and Ventilation of Barracks and Hospitals (*Army Med. Dep. Reports*, vol. vi. p. 229).

brought forward for this purpose.[1] After the great war, the exhaustion of the nation prevented anything being done, and in spite of the representations of many military men, comparatively little change occurred till the Crimean war. In 1855 a committee,[2] of which Lord Monck was chairman, was appointed by the War Office to consider this subject, and presented a most excellent Report on Barracks, the suggestions of which have been since gradually carried out. Immediately after this a Barrack Improvement Commission [3] was organised, and in 1861 this Commission published a Blue Book, which not only contained plans and descriptions of the existing barracks and hospitals, but laid down rules for their construction, ventilation, and sewerage, for future guidance. It is difficult to speak too strongly of the excellence of this Report; and where its rules have been attended to there can be no doubt the British army is, so far as habitations are concerned, lodged in healthier dwellings than almost any class of the community.[4] Reference must be made to this report for a fuller account of the older barracks and hospitals than can be given here.[5]

Infantry Barracks.

Block Plan.—Formerly a number of men, even a whole regiment, were aggregated in one large house, and this was often built in the form of a square (a plan originated by Vauban), the quarters for the officers forming one side, on account of the ease of surveillance. Many officers still prefer this form. But it is always objectionable to have an inclosed mass of air, and if it is adopted the angles should be left open, as recommended by Robert Jackson. The Barrack Improvement Commissioners very justly recommended that there should be division of the men among numerous detached buildings; and, instead of the square, that the separate buildings should be arranged in lines, each building being so placed as to impede as little as possible the movement of air on the other buildings and the incidence of the sun's rays.

In arranging the lines, the axis of the buildings should be if possible north and south, so as to allow the sun's rays to fall on both sides. One building should in no case obstruct air and light from another, and each building must be at a sufficient distance from the adjoining house, and this distance should not be less than its own height, and if possible more.

Parts of a Barrack.—1. The barrack room, with non-commissioned officers' rooms screened off. 2. Quarters of the married privates—seven to each company. (With the short service system this will probably be modified.) 3. Quarters of the staff-sergeants and sergeants' mess. 4. Quarters of the officers. 5. Kitchens. 6. Ablution rooms. 7. Latrines and urinals. 8. Orderly-room; guard-room. 9. Cells. 10. Tailors' shop and armoury;

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[1] On looking through the *Annual Register*, it will be found that Fox, as well as his followers, spoke strongly against the grant of sums of money for improving barracks. Their motives were good, and their jealousy of a standing army justified by what had gone before, but the result has been most unfortunate for the soldier.

[2] *Report of the Official Committee on Barrack Accommodation for the Army*, Blue Book, 1865.

[3] Mr Sydney Herbert, Drs Sutherland and Burrell, and Captain Galton, were the first Barrack and Hospital Improvement Commissioners. Lord Herbert did not sign the first Report, as he became Minister of War. Dr Burrell retired. The remaining Commissioners (Dr Sutherland and Captain, now Sir Douglas, Galton) subsequently published the *Report on the Mediterranean and other Barracks.*

[4] *General Report of the Commission appointed for Improving the Sanitary Condition of Barracks and Hospitals*, 1861.

[5] For the duties of medical officers with respect to barracks, see *Queen's Regulations*, 1885, section 15; and the *Army Medical Regulations*, 1885.

commissariat stores; canteen. 11. Reading-room (in many barracks); schools; magazine.

It is unnecessary to describe all these buildings.

The old barracks are of all conceivable forms and kinds of construction, for details of which see the Commissioners' Report.

When new barracks are built, the plans of the Commission are to be followed.

(*a*) *Barrack Rooms.*—The size and shape of the barrack room will decide the kind of buildings. The Barrack Committee of 1855 recommended that each room should accommodate 12 men, or one squad, as this is most comfortable for the men; but small rooms of this size are more difficult to arrange, and it is now considered best to put 24, or one section, in each room.

The Barrack Improvement Commissioners' recommendations may be condensed as follows:—

The rooms are directed to be narrow, with only two rows of beds, and with opposite windows—one window to every two beds. As each man is allowed 600 cubic feet of space,[1] and as it is strongly recommended that no room shall be lower than 12 feet, the size of a room for 24 men will be—length 60 feet, breadth 20 feet, height 12 feet. This size of room will give 14,400 cubic feet, or (600 × 24) enough for 24 men; but as the men's bodies and furniture take up space, an additional 2 feet has been allowed to the length in some of the new barracks. Assuming the length to be 62 feet, the superficial area for each man will be nearly 52 feet, a little more than 5 feet in the length and 10 in the width of the room. At one end of the room is the door, and a room for the sergeant of the section, which is about 14 feet long, 10 wide, and 12 high. At the other end is a narrow passage leading to an ablution room, one basin being provided for 4 men, and a urinal.

Such is the present arrangement of a single barrack room, and it is difficult to conceive a better plan, unless it might be suggested that an open verandah, never to be made into a corridor, should be placed on the south or west side. It would be a lounging-place for the men. So also a cleaning-room for arms and accoutrements would be a very useful addition.

The room thus formed may constitute a single hut, but if space is a consideration, two such rooms are directed to be placed in a line, the lavatories being at the free ends. A house of this kind will accommodate half a company. The several houses are separated by an interval of not less than 25 feet. For the sake of economy, however, the houses will in future be frequently made two-storied, so that one house will contain a company in four rooms, and ten will suffice for a regiment.

The three following plans of recently erected barracks show the arrangements which are adopted:—

1*st*, When there is a single story, as at Colchester, and no staircase is required.

2*nd*, When there are two storys, and a staircase must be introduced, as in the new cavalry barracks at York.

3*rd*, When there are not only staircases, but the barracks must be extended in one long line, including many rooms, and when, therefore, the ablution rooms cannot be put at the ends of the rooms, but must be placed on the landings, as at Chelsea.

If ten houses are thus formed, and arranged so as to insure for each the

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[1] In the French army the amount allotted is 14 cubic metres (495 cubic feet) for cavalry, and 12 cubic metres (424 cubic feet) for infantry, per head, the air to be changed at least *once* an hour.

greatest amount of light and air, the following area will be occupied by these houses alone. Each house (with walls) would measure about 140 feet long and 22 broad, and the space between the houses may be taken at 64 feet, or twice the height of the house. The external houses would, of course, have clear spaces on both sides like the others. The area of occupied and unoccupied space would be very nearly 12 square yards to a man.

But this amount of compression, which would be injurious in a large city, will do no harm in these well-planned and ventilated barracks.

(*b*) *Day-Rooms.*—The soldier lives and sleeps in his barrack room; it has long been a desideratum to introduce day-rooms,[1] but at present the expense is too heavy. Still it is very important that the men should take their meals elsewhere than in their barrack room, and in some barracks a room is provided close to the kitchen. The addition of a few verandahs to the rooms would be less expensive; and, if reading-rooms were provided, some of the purposes of day-rooms would be obtained.

(*c*) *Non-Commissioned Officers' Rooms.* — The Sergeant-major and Quartermaster-sergeant are entitled to two rooms and a kitchen; the Paymaster-sergeant, Schoolmaster-sergeant, and some others, are entitled to two rooms. The company sergeants have one room each. The rooms are about 14 feet by 12, and 10 high, and contain about 1680 cubic feet when empty. The amount of space is small, and as many of these non-commissioned officers are married, and as it is a matter of justice no less than of policy to make them as comfortable as possible, it is to be hoped that two rooms may be allowed to every married man, and three in the case of all the senior non-commissioned officers. The non-commissioned officers should be looked on in the light of the overlookers of a factory; they are even more essential to the good working of the army than the overlookers are in a mill; but no married overlookers would ever conceive the possibility of living in two rooms, in one of which cooking must be done.

(*d*) *Married Soldiers' Quarters.* — Seven privates in a company of 100 men are allowed to be married. Formerly they were placed in the men's barracks, a space being screened off, but now they are entitled to separate quarters, each family receiving one room 14 feet by 12, or 168 superficial and 1680 cubic space.

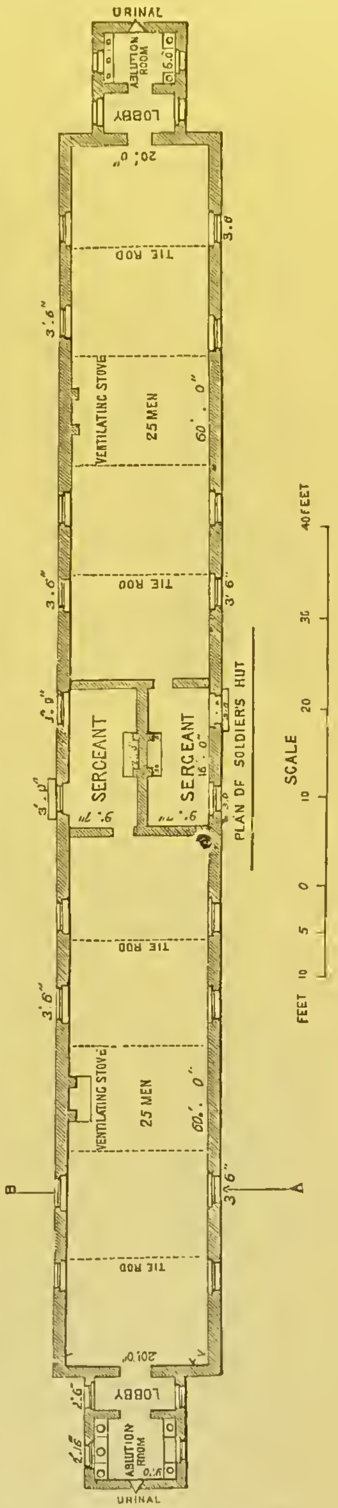

Fig. 97.—Colchester Camp Houses.

[1] See *Report of Committee* (1855), p. iv. The objections to day-rooms are—1*st*, more labour

There is no doubt that this allowance of space will be increased in accordance with the general feeling of the time, which is strongly against the mixing

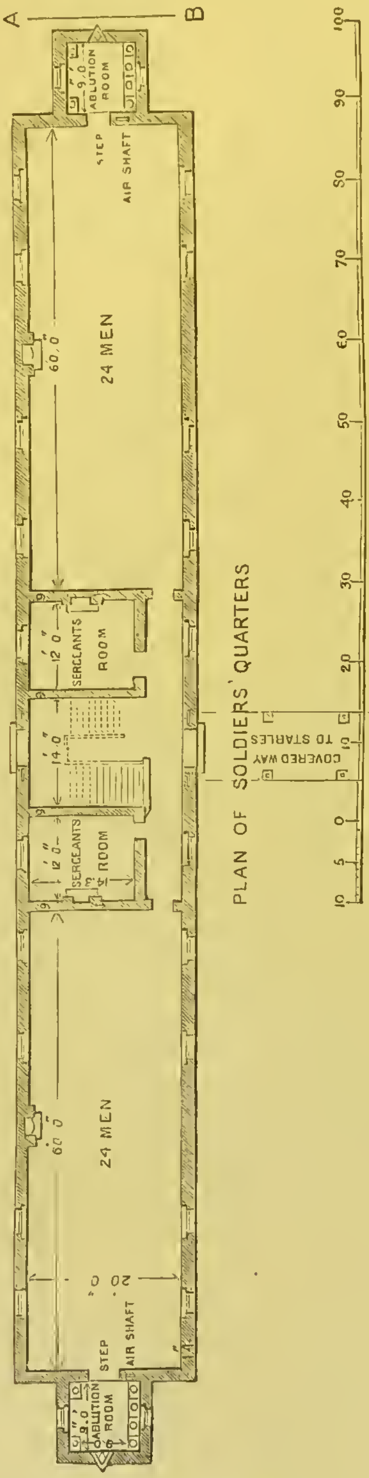

Fig. 98.—New Cavalry Barracks at York.

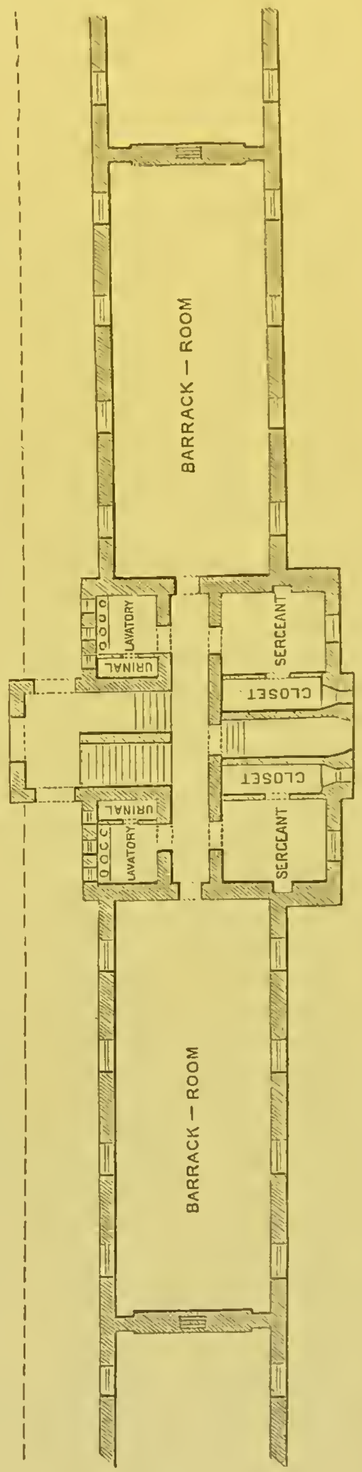

Fig. 99.—New Chelsea Barracks.

to keep clean; 2nd, chance of men being debarred from their barrack room during day; 3rd, chance of day-room being appropriated on emergencies. The Committee, therefore, recommend only dining-rooms for the men, to be arranged near the kitchen, if possible.

up adults and children of all ages in the same room. The amount of space also is really much too small. Certainly two such rooms ought to be given to each married private.

As no private is allowed to marry until he has completed seven years' service, the number of married privates must become fewer and fewer with the short-service system.

Warming of Barrack Rooms.—The rooms are warmed by Galton grates in two ways—radiant heat from an open fire, and warm air, which is obtained from an air-chamber behind, heated by the fire. The external air is led by a pipe to this chamber, and then ascending enters the room by a louvre. The grates are of various sizes, according to the size of the room. Smallest —1 foot 3 inches of fire opening for rooms of 3600 cubic feet. Middle—1 foot 5 inches for rooms of 3600 and 9800 cubic feet. Largest—1 foot 9 inches up to 12,000 cubic feet. Large rooms have two grates. One grate is usually provided for twelve men.

The radiating power of the small barrack grate is aided by a well-arranged angle, and by a fireclay back; as the fire is small, however, the radiating power is not great.

In the wards of Fort Pitt, with the largest size of grates, the mean rapidity of movement of warm air through the upper slits of the louvre, with a good fire, was found to be about $2\frac{1}{2}$ feet per second, and the total cubic amount of warm air entering per hour through the whole louvre was (approximately) 4600 cubic feet per hour, with a mean temperature of 19° in excess of the external air temperature. No unusual dryness of the air is produced by the admission of this quantity of warm air, the relative humidity of the air being about 70.

The movement of air through the hot-air louvres is not regular; open doors and windows, which increase the pressure of the air of the room on the louvre, will sometimes delay the movement, and, if the air-chamber is not very hot, will even reverse it and drive the air down, as the rapidity of movement in these hot-air chambers is never very great; but in cold weather, when the doors and windows are shut, the action is tolerably regular.

Ventilation of Barrack Rooms.—See under VENTILATION.

Ablution Rooms.—Formerly the means for washing were of a very rude kind, but now in the new barracks regular basins with clean water and discharge dirty-water pipes are provided close to every room, in the proportion of one basin to four men. The basins are of slate or iron. In several cases basins on the floor have been provided for feet-washing, and in some instances there are also baths for each regiment. The Barrack Improvement Commissioners recommend one bath to every 100 men. It is understood to be the desire of the Government to provide plunge-baths wherever practicable, and this would not only aid cleanliness, but might be made the means of teaching the men swimming, as suggested by Mr M'Laren.

If water be scarce, the most economical kind of bath is a shower-bath, so arranged as to permit 80 to 100 men to have a bath at once.

Inspections for cleanliness are made in many regiments. They should be systematically carried on under the direction of good non-commissioned officers; but, if means are provided, soldiers will generally be cleanly.

Kitchens.—Great improvements have been made in cooking by the employment of better ovens and boilers, and especially by making use of steam, as in Warren's cooking stoves. The cost of fuel per head has been greatly reduced.

The opinion of the medical officer will seldom be asked on the question of construction, at any rate on home service. He may, however, be referred to

on the question of consumption of fuel, and then he can take as the standard for an ordinary good apparatus $\frac{1}{2}$ lb of fuel per man per diem.

More often, however, he will have to examine the cooking, to which reference is made under the different sections in the chapter on FOOD. The chief points to which attention should be paid are the temperature, the rapidity of its application, and the ventilation of roasting ovens. Faulty cooking will generally be found to be owing to one or other of these conditions.

Formerly the regimental cooking establishment was badly arranged; men cooked by turns, and for short periods only. Now, cooks are regularly trained at Aldershot.

The other parts of a barrack are—officers' quarters; laundry (in some cases); workshops for tailor, shoemaker, and armourer; orderly-room; guard-room; cells; reading-room (in some cases); chapel and school, which are often in one; magazine; barrack-master's and quartermaster's stores for regimental purposes, bread, and meat.

Guard-Room.—The guard-room for a regiment of 1000 strong has a size of about 24 feet by 18; two rooms open into it—one a lock-up for prisoners, the other a room where prisoners are placed who are not put in the lock-up. In many barracks, however, the lock-up is placed near the cells. The guard-room is ventilated like the other rooms, with Sheringham valves, shafts, &c. M'Kinnell's ventilator is well adapted for it. It should be fitted with a drying closet by the side of the fire, to dry the men's clothes when they come in wet off sentry.

Cells.—The cells are ranged on one or both sides of a corridor. They are 10 feet long, $6\frac{1}{2}$ wide, and 9 high ($=605$ cubic feet), with one window, 2 feet 9 inches wide by 1 foot 3 inches high, placed at the top of the wall, and guarded by iron bars. A movable iron shutter is sometimes added for security, and to make the cell a dark one if needed. Fresh air is admitted through a grating opening from the corridor, which is warmed. The air enters below, or in some cases above; but the former arrangement is the best. A foul-air shaft runs from the top of the room. Two cells are provided for every 100 men. A medical officer inspects the cells every day.

Latrines and Urinals.—Formerly, urine tubs were brought into barrack rooms every night; and indeed this is still done in some barracks. The tubs are charred inside, and emptied every morning and filled with water during the day. In all new barracks urinals are introduced; they are placed at the end of the passage beyond the ablution room. It is found by the men that this is inconvenient; the passage is often wet and cold. If the urinal is full of water, it splashes; it might be well to put the overflow-pipe a little lower down. It has been recommended to put a small pipe and stopcock a few inches above the urinal, so that the men may cleanse themselves, and in this way possibly lessen the chances of syphilitic affection.

Cesspits are now discontinued in most barracks, and water latrines are used. The latrines are placed at some little distance from the rooms, and are usually connected with them by a covered way; in almost all barracks they are Jennings' or Macfarlane's patents. These are metal or earthenware troughs, which are one-third full of water. Twice a day a trap-door is lifted, the latrine is flushed, and the soil flows into a sewer or tank at a distance. A hydrant is now frequently placed close to the latrine; an india-rubber pipe can be connected with it, and the seats and floor of the latrine are thoroughly washed in this way twice daily. Automatic flush tanks might also be used. Probably it would be difficult to suggest anything better than this, although soldiers can be taught to use water-closets like other people, and do not

damage them. If water-closets are used, a plan suggested by Mr Williams, C.E., clerk of the works at Gravesend, seems a very good one. It is to have the water-closets at the top of a two-storied building, to the central part of which they form a small third story. In this way the following advantages are secured:—vicinity to the men—under the same roof, yet with perfect ventilation; impossibility of effluvia passing down; proximity to the cistern; and a good fall. At present, however, it seems better to keep to the water latrines outside the barracks.

Cavalry Barracks.

In many cases the men's rooms are placed over the stables, and there has been much discussion as to whether this arrangement is a good one. On the one hand, the men get more room, as the horses cannot be crowded, and they are near their horses. On the other hand, there is strong evidence that the effluvia from the stables pass into the men's rooms overhead;[1] and although no statistical proof has been furnished that this has produced sickness among the men, we may safely *a priori* conclude that it is objectionable. The evidence of mews in London is not in point, as they are often close, ill-ventilated courts, independent of the stables in them. Besides, this evidence is as yet rather contradictory.

The question has, however, been solved by a *Report on the Ventilation of Cavalry Stables* (1863),[2] by the Barrack Improvement Commissioners, who have shown that the ventilation and lighting of stables can only be satisfactorily carried out in one-storied buildings, and who, therefore, recommend that the men's rooms shall not be placed over stables.

Stables.—The medical officer has no duties connected with stables, except to see that they are in no way injurious to the health of the men; but it may be well to give the suggestions made by the Barrack Improvement Commissioners.

In all the old stables, if it is not already done, ventilating shafts are to be carried up, air-bricks introduced, and more window space to be given.

Whenever stables are to be built in future, it is recommended that the building should be one-storied; that the breadth should be 33 feet; the height of the side walls to the spring, 12; and of the roof, 8½ feet more. The breadth of each stall is to be 5½ feet, and there are to be only two rows of horses in each stable. Each horse is to have 100 superficial feet, and 1605 cubic feet; the ventilation is by the roof, and is formed by a louvre 16 inches wide carried from end to end, and giving 4 square feet of ventilating outlet for each horse. A course of air-bricks is carried round at the eaves, giving 1 square foot of inlet to each horse; an air-brick is introduced about 6 inches from the ground in every two stalls. There is a swing window for every stall, and spaces are left below the doors. In this way, and by attention to surface drainage and roof lighting, it is anticipated that stables will become perfectly healthy. Some experiments were made some years ago by Dr de Chaumont on the air of some artillery stables at Hilsea. In one stable, with 32 ventilators, and with 655 cubic feet per horse, the total CO_2 was 1·053 volumes per 1000; in another, with 1000 cubic feet per horse, and with 420 air-bricks, 25 windows, and a ridge

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[1] See especially the evidence of Mr Wilkinson, Principal Veterinary Surgeon to the Army; *Report of Barrack Committee* (1855), p. 136, question 2262; also the *Report on the Ventilation of Cavalry Stables* (1863). Smith's *Veterinary Hygiene*, 1887, may also be consulted.

[2] *Report of Barrack and Hospital Improvement Commission*, signed by Sir Richard Airey; Captain Galton, Dr Sutherland, Dr Logan, and Captain Belfield.

opening, it was 0·573 volumes per 1000. The last experiment shows great apparent purity of the air, but Mr F. Smith (Army Veterinary Department) has shown that such experiments are greatly affected by the presence of ammonia from the urine, and special precautions must be taken to get a really trustworthy result.[1]

Reports on Barracks.

The Regulations order the form in which reports on barracks shall be sent in. The arrangements should be strictly followed; it comprehends site, construction, external ventilation, internal ventilation, basements, and administration. It is then certain that no point will be overlooked; and, if nothing can be made out after going thoroughly through all the headings, it may be concluded that the cause of any prevailing sickness must be sought elsewhere. The site and basement should be especially looked at; every cellar should be entered, and the drainage thoroughly investigated. Little can be learned by merely walking through a barrack room, which is nearly sure to look clean, and may present nothing obviously wrong. With respect to ventilation, the statements of soldiers can seldom be trusted; they are accustomed to vitiated air, and do not perceive its odour. The proper time to examine the air of a room is about 12 to 3 A.M., and the medical officer should, accordingly, visit barrack rooms between midnight and 3 A.M. every now and then. The cisterns should be regularly inspected.

The walls and floors of the rooms should be carefully looked to. Walls are porous, and often become impregnated with organic matter. If there is any suspicion of this, they should be scraped and then well washed with quicklime. The medical officer should see that the lime is really caustic; chalk and water does little good. Collections of dirt form under the floors sometimes, and a board might be taken up to see if this is the case.

SUB-SECTION II.—BARRACKS IN FORTS AND CITADELS.

In fortified places it is, of course, often impossible to follow the examples of good barracks just given. Citadels may have little ground space; buildings must be compressed, guarded from shot, made with thick and bomb-proof walls, with few openings. Buildings are sometimes underground. Drainage is often difficult, or impossible; and if to all these causes of contamination of air we add a deficiency of water, which is common enough, it will not surprise us that the sickness and mortality in forts, in even healthy localities, are greater than should be the case. Both at Malta and Gibraltar there was for years too large a mortality from enteric fever, and from the destructive lung diseases, which appeared in the returns as phthisis. The special difficulties of casemates are as follows: dampness, which is very common in all casemates, so that the moisture often stands in drops on the walls; a low temperature; a want of ventilation; and a want of light.

How these difficulties are to be met is one of the most difficult problems the military engineer has before him. How, without weakening his defences, he is to get light and air into the buildings, and an efficient sewerage, would test the ingenuity of a Brunel. It is possible that the best plan would be by the employment of thick movable iron doors and shutters. In time of peace these might be open; in time of war easily replaced. But,

[1] See *Veterinary Hygiene*, 1887.

in addition, means of ventilation must be provided when such defences close the usual openings; tubes must be carried up, and, if necessarily winding, an enlarged area might, perhaps, compensate for this.

It must be said, also, that it is quite certain that in our fortified places many of the arrangements are much worse than they need be, and that the sanitary rules deducible from home experience should be applied in every case when the defensive properties are not interfered with.

Sub-Section III.—Barracks in Hot Climates.

The older barracks in both the East and West Indies were often merely copies of the English barrack square. In some cases, also, the exigencies of defence led to a cramped and irregular plan, and owing to the little attention which was paid either to the health or comfort of the soldier, overcrowding and deficient ventilation were as common in the tropics as at home. For several years there has been a gradual improvement, and in India especially vast and extensive palaces have been reared in many stations, which testify at any rate to the anxiety of the Government to house their soldiers properly.[1]

It will be desirable to refer here chiefly to the Indian barracks, but the same principles apply to all hot countries.

The Indian Sanitary Commission have recommended that each man in barracks shall have 100 superficial feet and 1500 cubic feet. The Government of India recommended in 1864 that there should be 90 superficial feet in the plains, and 77 in the hills, which, with a width of 24 and 22 feet, and height of 20 and 18 feet, would give 1800 cubic feet in the plains and 1408 in the hills. Mr Webb,[2] who paid great attention to the subject of overcrowding in Indian barracks, and who believed that it was the grand cause of insalubrity in India, adduced good reasons for thinking that this amount was not nearly sufficient. It is suggested, indeed, that 3000 cubic feet of space is not too much.

In 1857 and 1858 the Bengal Government ordered standard plans to be prepared, and some barracks have been built in accordance with them. A description and figures will be found in the former editions of this work. In 1863 the Governor-General of India in Council ordered a renewed inquiry into the matter, and Colonel Crommelin submitted altered designs for barracks, which were subsequently submitted to the Bengal, Madras, and Bombay Governments, and to the Army Sanitary Committee at home. The plan of these new barracks is essentially that proposed by the Indian Sanitary Commission; while the preparation of the detailed design is left to the local officers, certain general principles are strictly laid down, and standard plans suitable for different localities are furnished for guidance. The number of men to be placed under one roof is fixed at 40 or 50 (half company barracks), except under exceptional circumstances; the number

[1] Some of these great barracks, as at Allahabad, have not given satisfaction, and have been found as hot or even hotter than the old barracks. But this appears to have been from not attending to the rule never to let the sun's rays fall on a main wall, but to shadow the wall by a verandah. The double roof also has apparently not been sufficiently double, *i.e.*, the openings above and below, to allow the air to circulate, have not been large enough; ventilators have also not been put to the verandahs, so that the heated mass of air cannot ascend. Nothing tends to cause greater heat than stagnancy of the air, as may be seen by the ease with which water may be boiled in a close vessel by the rays of the sun, even in England. The objection to the palaces which have been built in India since the mutiny is not so much to the principle of the barracks, but to some faults in construction, and especially to their localities, viz., in the plains instead of in the hills in many cases.

[2] *Remarks on the Health of European Soldiers in India*, by H. Webb, Bombay, 1864, p. 50.

of men in one room is to be 16 to 20, and not to exceed 24; the barracks are to be two-storied in the plains, and one or two-storied in the hills, both floors being used for dormitories; single verandahs of 10 or 12 feet wide surround these rooms. There are to be only two rows of beds in the dormitories; the beds are to be 9 inches from the wall, and only two beds are to be in the wall space between two contiguous doors (or windows); in the plains each bed is to have $7\frac{1}{2}$ feet of running wall space, in the hills 7. The general arrangements of the building are based on the suggestions of the Royal Indian Sanitary Commission. At each end of the dormitory are closets and night urinals; and what appears to be the best plan places these at the extreme end of the verandah, leaving a space between them and the dormitory.

The lower story in the plains was intended to be used as a day-room, but it appears that this has not been comfortable for the men, and both floors are now used as dormitories.

The married people's quarters are to be grouped in small one-storied blocks, each block holding the married people of a company or troop. Two rooms (16 feet × 14 feet and 14 feet × 10 feet) are provided for each family; verandahs, 12 and 10 feet wide, are provided.

In all these arrangements it will be perceived that the essential principles of the home barracks are preserved; long, thin, narrow lines of buildings, with thorough cross ventilation, with the sleeping-rooms raised well off the ground, would certainly appear to be as good an arrangement as could be devised. A few more remarks on some of the points have to be made.

1. *Size of Houses.*—If there be no strong military reasons to the contrary, it seems certain that it is even more important in India than in England to spread the men over the widest available area, and not to place more than fifty men in a single block, and twenty-five men in a single room; and therefore the proposed plan is most desirable. There has been an objection raised, that small detached houses in the hot plains of India, not having any large space in shadow, get everywhere heated by the sun's rays, and become very hot. The objection is theoretical; it is the immense blocks of masonry used in the construction of large buildings which are to be avoided as much as possible, since, once heated, they take hours to cool.

2. *Arrangement of Houses.*—Broadside on to the prevalent wind, and disposition *en échelon*, as now adopted in India, is obviously the proper plan. The only exception will be when there are marsh or gully winds to be avoided, and then the houses should be placed end on to the deleterious wind; and no windows should open on that side. But it is seldom such a site would be selected or kept.

If a barrack is built on a slope, and the ground is terraced, the Army Sanitary Committee have recommended that the barrack should be placed end on to the side of the hill, and not nearer the slope than 20 to 30 feet. But terracing should be avoided as much as possible.

3. *Breadth of Houses.*—As in England, it is important to have only two rows of beds in each house, and to keep the houses under 30 feet in width, so as to permit effective perflation. A single verandah is as good as a double one in keeping off the direct rays of the sun from the walls of a house, and two verandahs (one inner and one outer) add to the breadth to be ventilated. The width of the verandahs must be 10 to 12 feet; and on the southern and western sides wooden jalousies may have to be placed so as to occupy 3 or 4 feet at the upper part of the verandah.

Verandahs should be ventilated by openings at the highest part, so as to have a free movement of air through them; this is very important. If there are two stories, the roof of the upper verandah should be double.

Materials of Building.—On this point there is little choice, for the risk of fire renders the use of wood undesirable for walls and roofs. And yet apart from this risk, loosely joined wood, or frames of bamboo, have the great advantage of allowing air to pass through the walls. Brick or stone has therefore to be used. In India, sun-dried brick (*kachā*), covered with cement, or faced with burnt brick, is often used; and the remains of Babylon or Nineveh show how imperishable a material this is if properly protected. It is said to be a cooler material than burnt brick (*pakkā*), but it absorbs a great deal of moisture.

Iron barracks were sent out from England during the mutiny, but were said to be hot, and were not liked; but iron frames have been usefully employed, the intervals being filled up with unburnt bricks. There is, however, a very general feeling against unburnt brick, on account of the moisture it absorbs and retains. The concrete walls now coming so much into use in England would be particularly adapted for India; they are cheap, and are dry.

Construction of the Building.—The three points to be aimed at are—avoiding the malaria and dampness of the ground, should there be any risk of this; insuring coolness; providing ventilation.

(*a*) *Employment of Open Arches for the Basement.*—The extraordinary diminution in the risk of malaria by elevating the building only a few feet above the ground, and allowing a free current of air under the house, is illustrated in various parts of the world: along the banks of the lower Danube, in the plains of Burmah and Siam, &c. But another great benefit is obtained: dryness and freedom from pent-up, stagnant, and often septic masses of air are insured, so that, even when the soil is not distinctly malarious, buildings should be raised. In a malarious country the height of the ground-floor above the ground should be 8 or 10 feet; in non-malarious districts 3 or 4 feet are sufficient, but it should always be high enough to allow cleaning.

If high enough, these open spaces afford excellent spaces for exercise during the heat of sun.

(*b*) *Walls.*—Very thick brick walls do not add to coolness (Chevers), but being thoroughly heated during the day, give out heat all night. The direct rays of the sun should not be allowed to fall on any part of the main wall. This will be found one of the most important rules for insuring coolness. Double main walls, with a wide space between, and free openings above and below, so as to admit a constant movement of air between, is the coolest plan known. Considering the excellent ventilation which goes on in bamboo and wooden houses, it may be a question whether, in the warm parts of India, the walls might not be made as far as possible permeable; at any rate, above the heads of the men. Whitening the outside walls reflects the heat, but is dazzling to the eyes; almost as good reflection, and much less dazzling, is obtained by using a slight amount of yellow or light-blue colour in the cement or lime-wash.

(*c*) *Floors.*—The materials at present used are flagstones (in Bengal), slates (in some barracks in the Punjab), greenstone (in some Madras barracks), tiles, bricks placed on end and covered with concrete, pounded brick and lime beaten into a solid concrete and plastered with lime, broken nodulated limestone or kankar (in places where the masses of kankar are found, as in Bengal), asphalt, pitch and sand, wood (Chevers). Of these various materials, the asphalt gets soft and is objectionable; the cements and kankar wear into

holes, produce dust, and have been supposed to cause ophthalmia (Chevers); wood is liable to attacks of white ants, &c.

On the whole, it would seem that good wood (if there be a space below the barracks) with brick supports is the best, and after this tiles.

(*d*) *Roofs.*—Double roofs are now usually employed, and are made slanting, and not terraced. The terraced roofs, if made single (*i.e.*, with battens on the joists covered with kankar), conduct heat too freely; but if made double, with a good current of air, there is an advantage in giving a promenade to the men, and also, at some seasons of the year, the roof may be most advantageously used as a sleeping-place.

The sloping roofs are better adapted for ventilation. The coolest roof is made of thatch, covered with tiles; it would be cooler still if the thatch were outside; but thatch is dangerous on account of fire, and harbours vermin and insects. If there is a good space between the two roofs (2 feet), and if there are sufficient openings to permit a good current of air, perhaps two tile roofs would be as cool as any.

(*e*) *Doors and Windows.*—These are now always made very numerous, and opposite each other, so as to permit perfect perflation. The official *Suggestions* order one window for every two beds. Five doors are recommended for each room of twenty-five men; and Norman Chevers gives a good rule: a light placed in the centre at night should be seen on all sides. Upper as well as lower windows—a clerestory, in fact—are useful; the lower windows should then open to the ground. In most of the stations in northern India the windows must be glazed.

The Committee appointed to carry out the suggestions of the Indian Sanitary Commission have recommended that each window should consist of two parts—the upper portion, about 2 feet in depth, being hinged on its lower edge to fall inwards, so as to direct the currents of air towards the ceiling of the room.

Ventilation of Tropical and Subtropical Barracks.

If barracks are not made too broad, and are properly placed, the same principles of ventilation may be applied to them as to barracks at home. The perflation of the wind should be obtained as freely as possible. The numerous doors and windows, however, render it unnecessary to provide special inlets; outlets should, as at home, be at the top of the room, either along the ridge, or, if of shafts, they should be carried up some distance; if they are made of masonry, and painted black, the sun's rays will cause a good up-current. The area of the shafts is ordered[1] to be 1 square inch to every 15 or 20 cubic feet, with louvres above and inverted louvres below. In the lower rooms these shafts are to be built in the walls; in the upper rooms to be in the centre.

In many parts of India, however, at particular times of the year, the air is both hot and stagnant; in such stations artificial ventilation must be employed, and the forcing in of air offers greater advantages than the method by aspiration. The wheel of Desaguliers was introduced into India many years ago by Dr Rankine, and, under the name of "Thermantidote," is frequently used in private houses and hospitals. Wheels may be used of a larger kind, and driven by horses and bullocks, or steam or water power. The great advantages are that the air is put in motion and can be cooled by evaporation.

[1] *Suggestions*, p. 22.

An Arnott's pump, made as large as a man can easily work, will be found to be cheaper, and as good as the thermantidote.

The common punkah is a ventilator, as it displaces masses of air; the waves pass far beyond the building, and are replaced by fresh air waves entering in. An improved punkah, worked by horse or bullock, and supplied with water for evaporation, was devised by the late Captain Moorsom of the 52nd Regiment; it is described and figured in the *Report of the Indian Sanitary Commission*, and would seem likely to be a very useful modification of the common punkah.

Ventilation in most parts of India must be combined with plans for cooling, and often for moistening the air.

Cooling of Air.—When the air is dry, *i.e.*, when the relative humidity is low, there is no difficulty in cooling the air to almost any extent. If the air be moving, this is still easier. The evaporation of water is the great cooling agency. A drop of water in evaporating absorbs as much heat as would raise 967 equal drops 1° Fahr., or, in other words, the evaporation of a gallon of water absorbs as much heat from the air as would raise $4\frac{1}{2}$ gallons of water from zero to the boiling-point. As the specific heat of an equal weight of air is $\frac{1}{4}$ that of water, it follows that the evaporation of 1 gallon or 10 ℔ of water will cool ($10 \times 4 \times 967$) 38,680 ℔ of air, or 477,637 cubic feet of air 1° Fahr.; or, to put it in another way, the evaporation of 1 gallon of water will reduce 26,216 cubic feet of air from 80° to 60° Fahr. If thoroughly utilised, $1\frac{1}{2}$ gallon per head would be the allowance for twelve hours, but as the full work is never got out of any material, this quantity ought in practice to be doubled. In India, the temperature of a hot dry wind is often reduced 15° to 20° by blowing through a wet kuskus tattie; but merely sprinkling water on the floors will have a perceptible effect on the temperature.

When the air is stagnant cooling is less easy. In India it is often attempted, in a still atmosphere, to insure coolness by creating currents of air either by the simple punkah or by thermantidotes; these act by increasing evaporation from the body, and they certainly do away with the oppressiveness of a still atmosphere. But evaporation of water must be also employed, as in Captain Moorsom's punkah just referred to, or in some other way.

In the case of a thermantidote, or Arnott pump, thin wet cloths suspended in a short discharge-tube, or ice suspended in it, or a bottle containing a freezing mixture, and with a wet surface, will answer equally well.

When water is abundant, other contrivances may be employed. A stream of water issues from a small orifice with a high velocity, and, impinging on a round iron plate about an inch or two from the orifice, is beautifully pulverised. Or the beautiful sheet-water fountains used to wash air for ventilation might be employed. In the old Roman, and some Italian houses, coolness was obtained by a fountain in the central court; and where it can be done, the more common employment of fountains in the houses in the hot parts of India may be suggested.

Cooling is, then, easy when the air is dry, or is not moister than 70 per cent. of saturation; but when the air is very moist, and almost saturated, as is often the case, for example, in Lower Scinde, and is at the same time still, evaporation is very slow. What can be done? Of course, the air must be set in motion by mechanical means. But how is it to be cooled? Two plans suggest themselves—taking the air through a deep tunnel, and the employment of ice.

The tunnel plan was tried some years ago at Agra, and was not well thought of. But everything depends on the mode of making the tunnel. It must be deep enough to get into a cold stratum of earth.[1]

The Chinese, in the north of China, suspend lumps of ice in their rooms during the summer; but this seems a wasteful plan. Ice in tunnels would have a much greater effect. If the ice cannot be obtained, freezing mixtures might possibly be used, if the expense were not a bar.

Ablution Rooms.—In India every private house, and almost every room in a house belonging to a European, has its bath-room. And not only the luxury, but the benefit is so great, that bath-rooms should be considered essential to every barrack. For the usual purposes of ablution, the plan now used on home service is the best; but it should be supplemented by shower-baths. In order that these shall be efficiently given, the old plan of carrying water by hand must be given up; shower-baths for a regiment could never be provided in this way; water in large quantity must be laid on in pipes, and cisterns at the top of every barrack should feed the ablution rooms and supply water for the urinals. At least from 12 to 18 gallons daily should be allowed per head for shower-baths alone, and if possible, more than this, as general baths should be also provided. So essential must baths be considered for health, that a large supply of water should be considered a necessary condition in the choice of site. The disposal of the water after use is a question for the engineer; but it must not be permitted to soak into the ground near the barracks; it might seem superfluous to notice this, if the custom of allowing the ablution water to run under the houses did not prevail at some stations.

Urinals.—Urine tubs are still used in many of the barracks in India, but their use should be discontinued as soon as possible. Evaporation is rapid, and decomposition soon sets in. Several army surgeons have pointed out that the atmosphere is greatly contaminated in this way, and some have considered that affections of the eyes are produced by the ammoniacal fumes. Earthenware or slate urinals should be used, with water running through them; and if there are no drains to carry off the urine, a zinc pipe may be laid inside the building, and open into a tub below, which should be emptied daily.

The War Office Committee[2] recommended Mr Jennings' urinal, which consists of a basin, valve, and siphon-trap, supplied with water. It is cleaned and filled by raising the handle. As already noticed in the Home Barracks, the suggestion of a small water-tap above, to allow the means of ablution, seems an excellent one.

Sub-Section IV.—Wooden Huts.

Of late years the use of wooden huts, both in peace and war, has greatly extended in several of the European armies. In peace, their first cost is small, and they are very healthy. In war, they afford the means of housing an army expeditiously, and are better adapted for winter quarters than tents.

The healthiness of wooden huts doubtless depends on the free ventilation; when single-cased, the wind blows through them; and even when double-cased there is generally good roof and gable ventilation.

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[1] The recent investigations into the composition of the ground air give additional reasons for objecting to the tunnel plan, unless the utmost care were taken to prevent the ground air being delivered into the dwellings.

[2] *Suggestions*, p. 24.

Numerous patterns of huts have been used in our own and other armies, from small houses holding six men to the large houses designed by Mr Brunel for Renkioi Hospital, and which were 25 feet high in the centre, 12 feet at the eaves, and held 50 men. In the Crimea the most common sizes were for 12, 18, and 24 men. Lord Wolseley thinks the most useful size is 32 feet long, 16 wide, 6 feet to eaves, and 16 to ridge, to hold 28 men; two huts are put end to end, with one chimney between them. If protection has to be obtained against wind, make a wall a foot away.

In arranging lines of huts, as much external ventilation and sunlight must be secured as possible for every hut. According to circumstances, the arrangements in lines, or *en échelon*, &c., must be adopted.

In time of peace huts are sure to be put up well; to be properly underpinned; on a drained site, and well warmed.

War Huts.

In the putting up of huts in the time of war, when everything is done more roughly, the following points should be attended to:—

Do not excavate the ground, if possible; and never pile earth against the sides.[1]

(*a*) *Floor.*—Whenever practicable, underpin the joints, so as to get a current of air under the floor. Arrange for the drainage underneath, so that water may not lie, but may be carried by a surface drain at once to an outside drain. If the floor is entirely of wood, have it screwed, and not nailed down,[2] so that the boards may be taken up, and the space below cleaned. If the sides are of planks, and the centre of earth, pave the centre with small stones, if they can be got, so that it may be swept. If this cannot be done, remove a little of the surface earth every now and then, and put clean sand or gravel down.

(*b*) *Sides.*—If the sides are double, leave out a plank at the bottom of the outside, and at the top of the inner lining. If the sides are single, make oblique openings for ventilation above the men's heads, with wooden flaps falling inwards, and capable of being pulled more or less up, and inclosing the opening. Place a plank obliquely along the bottom at the outside, to throw the drip from the roof outwards, so that the water may not sink under the houses. Whitewash both inside and outside of the planks.

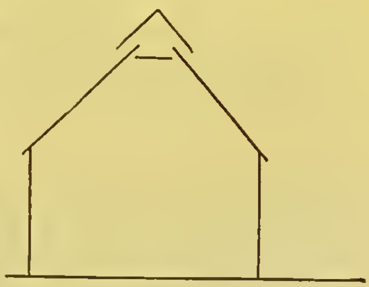

Fig. 100.

(*c*) *Roof.*—Arrange for ridge ventilation. If felt is used, let the strips run along the sides, and not over the ridge, and beginning at the bottom, so that each successive strip may imbricate over the one below it; use no nails, but place thin strips of board across the strips from the ridge downwards, to hold the felt down. Tarred calico is as good as felt.

Warming.—In cold countries, if stoves are provided, place them at one

[1] While it is desirable to have the walls as clear from accumulations outside as possible, it must be remembered that this rule, like others, has its exception. Thus, in a very cold country, like Canada, a sufficient degree of warmth could not be obtained in a wooden hut without piling snow up against the sides.

[2] If possible, the screws should be of copper, not iron; if of iron, each screw ought to be dipped in oil before being put in: this greatly increases the ease with which they can be withdrawn, and also saves the wood to some degree.

end, and let the chimney run horizontally along above the tie-beams, to the other end, and open at the gable; in this way the heat is economised ; or put a casing of wood round the stove, except in front, and allow fresh air to pass between the stove and casing. If no stoves are provided, and a fire-place is made with stone, it should be put at one end, and a wooden trough running out at the gable be used as a chimney. If a good broad slab of stone can be obtained for a hearth-stone, dig a trench under the boards and lead the air from outside under the hearth-stone, and provide an opening at the other side of the stone. In this way the entering air is warmed.

Trenches should be carried round huts as in the case of tents.

Fig. 101 shows a plan much used by the Germans in 1870–71 for temporary sheds; the crossing of the rafters permits thorough roof ventilation, and the raising from the ground where practicable is very important.

Causes of Unhealthiness of Wooden Huts.

1. *Dampness from Ground, Earth against Wall, &c.*—Drain well. Cut away ground from outside; have good trenches round, with a good fall.

2. *Substances collecting under Floors.*—Look well to this as a common cause of unhealthiness.

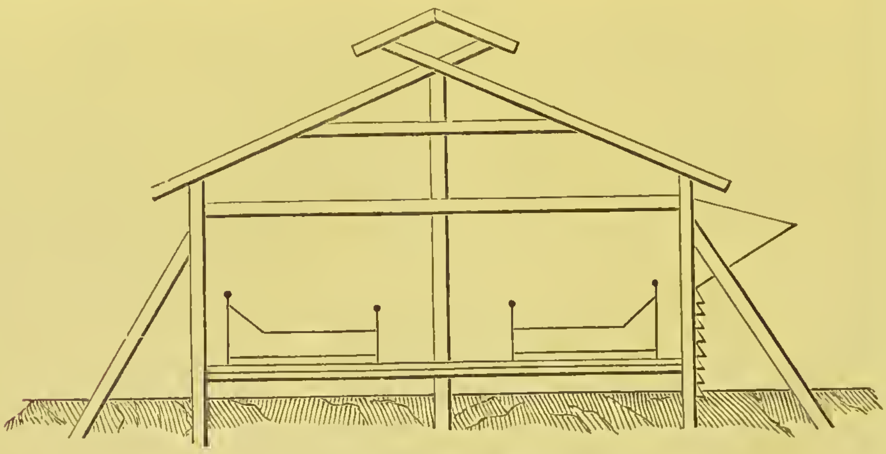

Fig. 101.—Plan of German Shed.

3. *Earth round Huts saturated with Refuse, Urine, &c.*—Every now and then clear away the surface earth, and replace it with clean dry earth.

4. *Ventilation* bad from too few openings.

5. *Cold.*—Issue extra clothes, if additional fuel cannot be obtained. See that the greatest effect is obtained from the fuel; but do not, if it can possibly be helped, close the ventilators.

Sub-Section V.—Tents and Camps.

Tents.

A good tent should be light, so that it may be easily transported, readily and firmly pitched, and easily taken down. It should completely protect from weather, be well ventilated, and durable.

It is perfectly easy to devise a tent with some of these characteristics, but not to combine them all.

The tents used in our army are as follows :—

Home Service.[1]

The Circular or Bell Tent.—A round tent with sides straight to 1 foot high, and then slanting to a central pole. Angle at apex, 70°. Diameter of base, 12·5 feet; height, 10 feet; area of base, 123 square feet; cubic space, 492 feet; weight, when dry,[2] about 65 to 70 lb. The canvas of the new pattern is made of cotton or linen. The ropes extend about 1½ feet all around. It holds from twelve to sixteen men; and in war time eighteen and even twenty have been in one tent. The men lie with their feet towards the pole, their heads to the canvas. With eighteen men, the men's shoulders touch. Formerly, there was no attempt at ventilation; but afterwards a few holes were made in the canvas near the pole. Ventilation, however, was most imperfect.[3] Dr Fyffe (formerly of the Army Medical School), who carefully examined this point, found the holes so small that the movement of the air was almost imperceptible. There is little ventilation through the canvas, and none at all when it is wet with dew. The new circular tent is somewhat improved as regards ventilation.

The Hospital Marquee.—An improved hospital marquee was issued in 1866. It is in principle the same as the old marquee, but with improved ventilation. This tent is two-poled, with double canvas. It is made of a lower, almost quadrangular part, and an upper part, sloping from the top of the straight portion to the ridge. Length, 30 feet; breadth, 15; height of sides, 5; height to ridge, 15; area about 385 square feet; cubic space, 3336 cubic feet.

It is intended for sick, and can accommodate ten men well; sixteen is the regulation, and twenty-four men have been put in it; but this crowds it extremely. There are ventilators, and a large flap at the top can also be opened for ventilation, and the fly can be raised. Its weight (including the valise) is about 512 lb dry and 660 lb wet. A waterproof sheet is now supplied, to put on the ground, and this weighs 145 lb.

It is a good tent when care is taken with ventilation; but there should be a way of raising one whole side, so as to expose every part of the tent; and if the height of the upright part were 6 feet, it would be more convenient.

Lord Wolseley[4] condemns the hospital marquee as cumbersome, excessively heavy, and difficult to pitch.

Circular Tent.—A double circular tent, with higher walls and without lining, weighing about 100 lb, has been approved of for hospital purposes, into which four sick or wounded men are placed. This forms part of the new field equipment. Five such tents accommodate twenty men well, whereas the marquee of the same weight only serves for ten, unless unduly crowded.

Shelter Tent.—There is no official shelter tent for the English army on home service, but one was formerly issued for service at the Cape, and one is still occasionally issued on campaign, weighing 11 lb, for two or three men. Each man at the Cape carried a canvas sheet, made up of a quadrangular (5 feet 9 inches × 5 feet 3 inches) and of a triangular piece (2 feet 8 inches height of triangle × 5 feet 3 inches base). Buttons and button-holes were sewn along three sides, and a stick (4 feet long, and

[1] For measurement of tents, see the *Soldier's Pocket-Book*, by Lord Wolseley, 5th edition, 1886.

[2] Complete wetting of a tent adds from 30 to 40 per cent. to the weight.

[3] *Barrack Improvement Report*, p. 107.

[4] *Op. cit.*, p. 103.

divided in the middle) and three tent pegs and rope also were provided. Two or four of these sheets could be put together, the triangles forming the end flaps. A very roomy and comfortable shelter tent, 4 feet in height, was formed, which would, with a little crowding, accommodate six men, so that two sheets could go on the ground. The objection to this tent was its weight, viz., 6 ℔ 14 ounces per man. If a thinner material could be obtained, and if the size could be a little lessened in all directions, it would be a very good tent. Dr Parkes attempted to arrange a cape and waterproof sheet in such a way as to form a tent when suspended on rifles.[1] A plan for making a shelter tent with blankets is given in the *Instructions for Encampments*, 1877, p. 19, paragraph 14.

Lord Wolseley[2] condemns the shelter tent as too heavy and not fulfilling its purpose.

Officers' Tents.—Marquees are allowed, one for each field-officer; each captain, and every two subalterns, have one circular tent. The officers' marquee weighs 176 ℔.

On Indian Service.

The tents for Europeans are marquees, with two poles and ridge, double fly. Length, 22 feet; breadth, 16; height to inner fly, 10 feet 3 inches; and outer fly, 11 feet 9 inches; weight, 600 ℔ to 631 ℔. Twenty-five infantry are accommodated with 85 cubic feet per man; or twenty cavalry, with saddles, with 100 cubic feet.

The tents for natives have a single fly. The Sepoy double pāl, new pattern, weighs 512 ℔, and has the following dimensions:—length, 32 feet; breadth, 16; height of pole, 8·5 feet, tapering down to 1 foot at the sides; to accommodate twenty-two[3] British, forty-four native soldiers, or fifty followers. The old pattern Lascar pāl is exactly half the above size; a useful tent everywhere (Wolseley); it weighs 248 ℔. Officers in India provide their own tents: limit of weight, 80 ℔.

French Tents.—In the French army two chief kinds of soldiers' tents have been used.

1. The *tente-abri*, or shelter tent of hempen canvas, which was intended for three or four men. This is now given up, except in campaigns beyond the confines of Europe.

2. *Tente de Troupe*, or *Tente Taconnet.*—This is a two-poled tent, with a connecting ridge-pole; for sixteen men. It is considered cumbersome and unstable, and is now being abandoned.

3. Two conical tents are now used, like the English bell tent; one (*tente conique*, also *tente turque*, or *à marabout*) a cone, and the other having an upright wall 16 inches high, and then being conical above (*tente conique et á murailles*). This last tent is ventilated at the top; a galvanised iron ring, 12 inches in diameter, receives the canvas, which is sewed round it. An opening is thus left of 113 square inches, which can be closed by a wooden top which rests on the top of the pole, and is buckled to the ring. Each tent holds. twenty men. The *tente conique* is the one now chiefly used. Small tents, called *tentes de marche*, are now issued to officers, who formerly provided their own various forms.

Prussian Tent.—This is a conical tent, with a single pole, like the bell

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[1] *Army Med. Depart. Report* for 1870; 1872, p. 260.

[2] *Op. cit.*, p. 254.

[3] Surgeon H. K. Mackay, 32nd Panjāb Pioneers, says the usual number is twenty, and eighteen when the full guards are formed.

tent of the English army; it is nearly 15 feet in diameter, the pole is 12 feet high: it holds fifteen men, and weighs 91 ℔ avoir. The floor space is 12 square feet and the cubic space 70 cubic feet per head.

Prussian Hospital Tent.—The ground floor of the tent is a rectangle 62 feet long and 24 broad; the tent is 16 feet high; there are six or eight poles; the area is 1488 square feet. It is divided into three parts: a central, 52 feet long and 24 broad (=1248 square feet), for the sick, and two rooms, each 5 feet long and 24 broad, for attendants, utensils, &c. Some of the tents are made with hollow iron poles, and there is a good hood for ventilation. Each tent could contain 20 to 22 beds, but only twelve patients are placed in it. It stands on an area of 80 feet by 40. Since 1862 the Prussians have treated many of the worst cases under such tents during the summer. The same practice has been adopted in the Austrian army for many years.

Russian Tent.—The infantry tent is quadrangular, 14 feet square and 7 feet high to the slope; there is a centre pole and four corner poles; it is intended for fourteen men, but only twelve are usually placed in it. Round the tent is a bench $1\frac{1}{2}$ foot broad, and covered with straw mattresses and sheets (in the summer camps) for sleeping. A wooden rack round the centre pillar receives the rifles. The canvas can be partly or entirely lifted up. The officers' tents have double canvas.[1]

North American Tents.—At the commencement of the civil war the Sibley tent was much used. It is conical, 18 feet in diameter, and 13 feet high, with an opening for ventilation, and gives 1102 cubic feet; often twenty or twenty-two men were held by one tent. Bell and wedge-shaped tents were also used; the latter was 6 feet 10 inches long, 8 feet 4 inches broad, and 6 feet 10 inches high, with a cubic space of 194 feet. It held six men.

These tents, however, did not answer—the ventilation was most imperfect; and in the summer of 1862 ponchos and shelter tents were issued, which in the army of the Potomac superseded the old tents.[2] The poncho is a piece of oil-cloth with a slit in the centre, through which the head is put; two ponchos can form a shelter tent. The army of the Potomac spent the winter in improvised huts of logs or mud, with the shelter tent for the roof. The larger tents are, however, still used for stationary commands, and for hospital purposes.

General Conclusions.

Although it has been affirmed that it will be henceforth impossible to carry tents during war in Europe (Wolseley), yet the history of all wars in the temperate zone proves that men cannot war without protection from weather.[3] Both theory and experience show that the best arrangement for a soldier is that he should carry a portion of a shelter tent, which may at once serve him for a cloak on the march, and a cover at night, if he is obliged to lie out without pitching his tent, and which, joined to two or three other similar pieces, may make a tent to hold three or four. The French, however, have abandoned this system, believing that its advantages are more than counterbalanced by the extra weight the men have to carry.

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[1] From Heyfelder's *Camp of Krasnoe-Selo*, 1868.

[2] Woodward, *Outlines of the Chief Camp Diseases of the United States Army*, 1863, p. 46.

[3] The Franco-German war of 1870–71 does not negative the rule that shelter must be given in some way; the Germans in their camps hutted themselves, and in their marches found shelter in houses in the greater number of cases.

For camps of position, where troops are kept for months, and where there is less trouble about transport, larger tents can be used.

The French system, now adopted by the Americans, is in reality a very old one. The Macedonians used small tents which held two men,[1] and Rhodes figures a little shelter tent of the same form as the French, and holding apparently five men, which was in use in the British army in 1750.

At various times in late wars the English army have extemporised tents of this description, by suspending blankets over their firelocks. But it would be much better to have a good shelter tent, which would make the men independent of their bell tents, on emergency, and thus greatly lessen the baggage of the army, as well as protect the men.

An army could then encamp and house itself as fast as it could take up its ground, and so short is the time necessary for pitching the tent that even in heavy rain the men would not get wet. The men lie much more comfortably than in the bell-tent,[2] and there is scarcely a possibility of its being blown down.

Camps.

Several regulations have been issued by the Quartermaster-General's Department,[3] and the *Queen's Regulations*[4] contain several orders which will be noticed hereafter. The Barrack Improvement Commissioners[5] also lay down certain rules which must be attended to.

Encampments are divided into two kinds—those of position, which are intended to stand for some time, and incidental camps. The camps are arranged in the same way in peace and war, as a means of training the men; but, of course, in peace the war arrangements need not be adhered to.

In the *Regulations and Instructions* issued in 1877 by the Quartermaster-General's Department, the following rules are laid down :—

1. That the means of passing freely through the camp should be maintained.

2. That the tents, bivouacs, or huts should be disposed with a view to the greatest amount of order, cleanness, ventilation, and salubrity.

3. That the camp be as compactly arranged as possible, consistently with the above considerations.

Troops are ordered to be encamped in such a manner that they can be rapidly formed in a good position for action. This does not involve the necessity of encamping on the very position itself.[6] Although purely strategical or tactical considerations are of the first importance before an enemy, yet sanitary advantages must always be allowed great weight, and will, in most cases, govern the choice of ground if military reasons permit. Cavalry and infantry camps are directed to be formed with such intervals between their troops or companies as circumstances may require, or the general commanding may direct. Open column is usually the most extended order used.[7]

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[1] Rhodes' *Tent Life*, p. 13.

[2] In some of the last China expeditions waterproof sheets were issued, of which the men made tents as well as cloaks. Dr Parkes was told by a private soldier who carried one of these, that nothing more comfortable was ever issued to the men. His sheet was the last thing that a man would part with.

[3] *Regulations and Instructions for Encampments*, "Horse Guards," 1877. A great deal of very important information is given in this little book.

[4] 1885, section 8.

[5] *Report*, 1861, p. 168.

[6] *Regulations and Instructions for Encampments*, p. 1, section ii.

[7] Measurements in infantry camps are usually made in paces: 6 paces=5 yards; other camps are measured in yards.

In front of the camp is the battalion parade, the quarter-guard being in front of all. Behind the men's tents are the kitchens, and behind these the tents of the officers; then come the wagons, horses, drivers, and bâtmen; next the ashpit and latrines, and on the boundary line the rear-guard. In fixed camps the latrines and kitchens may be pitched elsewhere, if found advisable.

The distances between different corps are, as a rule, to be 30 paces.

Cavalry are encamped in the same way, in columns of troops or squadrons; 4 feet of space is allowed to each horse, which is picketed.

Artillery encamp with the guns in front, the waggons in two lines behind, and the horses and men on the flanks, the men being outside, the officers' tents being in rear. A battery of artillery, with 192 of all ranks, and 154 horses, occupies a space of $175\frac{1}{2}$ yards by 133 in open order, and 85 by $71\frac{1}{2}$ in close order. Other arrangements are given in the *Regulations*.[1]

An infantry camp for 1096 officers and men is 320 yards × 266, with an interval of 25 yards between corps. This gives 84 square yards per man, or 36,802 men per square mile. According to Wolseley, a camp may be compressed to 120 × 150: this gives (with the interval) 20 square yards per head, or 154,665 men per square mile. The actual ground covered by tents and intervals would give in open formation 12 square yards per man, and in close formation 8 per man; this last is equal to a space of 120 square yards (nearly 11 yards square) per tent of 15 men, or 387,200 men per square mile. The smallest space tents could occupy would be back to back, a double line of 28 feet, with a yard gangway. This would give 24 square yards per tent, 5·2 × 3·6 yards. The space per man would be 1·6 square yards, or equal to 1,936,000 men per square mile.

On considering these arrangements, it is evident that the compression of the men, even in open order, is considerable. As in war it is not always easy to give space, the importance, even in a military point of view, of thoroughly ventilating the tents is obvious. It is to be presumed that no military officer who regards the comfort or health of his men will ever compress his camp without an imperative military necessity. Yet it has been occasionally done, and tents have been placed almost as closely as they could be, even when ground was available, and no enemy was in front. Under these circumstances, an explanation of the reasons for not crowding the men together will undoubtedly satisfy the officer in command that he is sacrificing comfort, convenience, and efficiency to a false notion of order and neatness.

In the Crimea many officers dug out the interior of their tents, leaving a small pillar of earth to support the pole; a ledge of about 9 inches in width was also left all round the outside to serve as a shelf; a great deal of comfort and shelter was thus given in cold winds, but it would be well to go to as little depth as possible unless the soil is dry.

Points to be attended to in the Erection and Conservancy of Camps.

Dig a trench round each tent, 4 inches deep, and the width of the spade, and carry it into a good surface drain running in front of the tents, with a proper fall. Place the tent on the ground and do not excavate, or only to a slight extent; in a camp of position, the tents can sometimes be raised on a

[1] For numerous plates of camps, tents, kitchens, &c., the reader is referred to the *Instructions and Regulations for Encampments*, price 6d., which ought to be in the hands of every officer. Consult also the *Soldier's Pocket-Book*, by Lord Wolseley, 5th edit., 1886.

wall constructed of stones, or even earth, if this can be plastered over. Whenever possible, let the floor of the tent be boarded, the boards being loose, and able to be removed. If there are materials, make a framework elevated a few inches from the ground to carry the boards. If boards cannot be obtained, canvas or waterproof sheets should be used; whatever is used, take care that nothing collects below, and move both boards and canvas frequently to see to this, and scrape the earth if it is at all impregnated. If straw is used for bedding, get the men to use it carefully; to place pegs of wood or stones, and make ropes of straw running from peg to peg, so that each man may keep his own place neat; or to make mats of straw of a triangular shape, and 3 or 4 inches thick. Take care that the straw is kept dry, and never allow the men to use green foliage, or any damp substance. Have the sides of the tent thoroughly raised during the day, and even at night, to leeward. Whenever practicable (twice a week if it can be done), the tents should be struck, the boards taken up, the surface well cleaned, the worst part of the straw removed and burnt.

In a camp of position dry paths should be constructed between the different roads; latrines should be dug in rear of the stables, and not too near the kitchen, and *en échelon* with the camp; for a standing camp each latrine should be a trench 20 to 50 feet long, according to the size of the camp, 10 deep and 3 wide at the top, and 2 at the bottom. The earth thrown out should be arranged on three sides. It should be screened by branches of trees, and several inches of earth should be thrown in every day.[1] When 4 feet from the surface, it should be filled in and another dug, the earth of the old one being raised like a mound to mark the spot. Close to it a urinal should be constructed, of a sloping channel paved as well as can be, and leading into the latrines, or of a tub which can be emptied into it, and, as far as possible, men should be prevented from passing urine round their tents. In camps for a few days a trench 12 paces long, 2 feet deep, 2 feet wide at top and 1 foot at bottom, is sufficient.

A corps of scavengers should be immediately organised to clean away all surface filth, and to attend to the latrines and urinals. All refuse must be completely removed; it is a good plan to burn it. Both in peace and war, encamping ground should be often changed, and an old camp should never be re-occupied.

In addition to tents, the men may be taught, if possible, to house themselves. Huts of wattle should be run up, or wooden sheds of some kind. In war, men soon learn to house themselves. Luscombe gives the following account of the huts in the Peninsula :—

"A cork tree or evergreen oak with wide-spreading branches was chosen, a lower branch was nearly cut through, so as to allow the extreme points to drop to the ground. Other branches were then cut from adjoining trees and fixed in a circle in the ground, through the branch, on which their upper branches rested. Smaller branches were then interwoven to thicken the walls, and the inside was lined with the broom-plant, which was thatched in. The door of the hut was put due east, so that the sun might pass over it before it reached the horizon."

This hut was very cool during the day, but *very cold* at night, and thus "very prejudicial to health."

Lord Wolseley states that many English officers, and the Sardinians generally, in the Crimea, made comfortable huts in the following way :—A space was dug out $2\frac{1}{2}$ feet deep, and the size of the hut; those made to

1 The *Regulations* direct 2 or 3 inches of earth.

contain 6 Sardinian soldiers were 14 feet 3 inches long, and 7 feet 1 inch wide in the clear. Gables were then built of mud or stone, or made of boards or wattle and daub; the gables were 2 feet wider than the excavation, so as to form a shelf all round; a door was in one and a window in the other. The fireplace was made of brick or mud, or simply cut out of the face of the earth in one of the side walls, a flue being bored in a slanting direction, so as to come out clear of the roof, and being provided with a chimney 2 feet in height. The pitch of the roofs should be at an angle of 45°.[1]

Underground huts are sometimes used in camps; they are, however, dangerous; they are often damp, and are difficult of ventilation. In cold dry countries, however, they are warm, and the Turks have constantly used them in campaigns in winter on the Danube. They have, however, frequently suffered from typhus. If used, there should be two openings besides the chimney, so as to allow a current of air; and a spot should be chosen where it is least likely water will gravitate. But underground huts are always to be discouraged if any substitutes can be found. Sometimes the side of a hill is cut into, and the open top covered with boards and earth. This is as bad as an underground hut.

Hospital Encampment.

The arrangements for Field Hospitals are given in the *Medical Regulations*, 1885. As before said, Circular Tents, one to four patients, are those now employed, although marquees may be used when available. For the late Surgeon-Major Moffitt's plan of encampment, see previous edition of this work.

SECTION II.

THE FOOD OF THE SOLDIER—ARMY REGULATIONS.

The *Army Medical Regulations* place the food both of the healthy and sick soldier under the control of the medical officer. He is directed to ascertain that the rations of the healthy men are good, and that the cooking is properly performed; the amount of food for the sick is expressly fixed. On taking the field, the principal medical officer is ordered to advise on the subject of rations, as well as on all other points affecting the health of the troops. It will thus be seen that a great responsibility has been thrown on the Medical Staff, and that its members will be called upon to give opinions on the quantity of all kinds of food supplied to soldiers; on the composition of diet; on the quality and adulteration of the different articles; and on their cooking and preparation.

In the case of soldiers and sailors, definite quantities or rations of food must be given. It is, of course, impossible to fix a ration which shall suit all persons. Some will eat more, some less, but certainly every scale of rations should err on the side of excess rather than defect.

The following are the rations of the chief European armies:—

English Soldier on Home Service.

The English soldier receives from Government 1 lb of bread, and $\frac{3}{4}$ lb of meat, and buys additional bread, vegetables, milk, and groceries. The following table shows his usual food:—

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[1] Drawings of various kinds of huts and bivouacs are given in the *Regulations, op. cit.*

Nutritive Value in Ounces (avoir.) and Tenths of Ounces.

Articles.	Quantity taken daily in oz. and tenths of oz.	Water.	Nitrogenous Substances.	Fat.	Carbo-hydrates.	Salts.	Total Water-free Food.
Meat,	12 oz. (of which ⅛th is bone).	7·20	1·44	0·81	...	0·15	2·40
Bread,	24 oz.	9·60	1·92	0·36	11·81	0·31	14·40
Potatoes,	16 „	11·84	0·32	0·02	3·36	0·02	3·72[1]
Other vegetables,[2]	8 „	7·28	0·14	0·04	0·46	0·06	0·70[1]
Milk,	3·25 „	2·82	0·13	0·12	0·16	0·02	0·43
Sugar,	1·33 „	0·04	...	...	1·29	0·00	1·29
Salt,	0·25 „	...	...	...	...	0·25	0·25
Coffee,	0·33 „	...	...	...	...	...	...
Tea,	0·16 „	...	...	...	...	...	...
Total quantity,	65·32 oz.	38·78	3·95	1·35	17·08	0·81	23·19

Calculating this by the table given at page 245, it would give—

		Grains.
Nitrogen,		276
Carbon in albuminoids,	837	4588
Carbon in fats,	454	
Carbon in carbo-hydrates,	3297	
Hydrogen in albuminoids,	32	97
Hydrogen in fats,	65	
Sulphur in albuminoids,		32

The quantity of nitrogen is considerably below that of the standard diet, while the amount of carbon is nearly correct, only this is given chiefly in the form of carbo-hydrates, and not as fat. The diet would be improved by the addition of more meat or of cheese, and by the addition of butter or of oil. So also, while fresh succulent vegetables are sufficient, the use of peas and beans, as in the French army, would be very desirable.[3]

Using the table at p. 248, and taking the bread ⅙th crust and ⅚ths crumb and the "other vegetables" as cabbage, the total energy obtainable in the body from the soldier's daily diet appears to be equal to lifting 3542 tons one foot. The amount for the internal and external mechanical work of the body being taken at 600 tons lifted a foot, there remain 2942 tons for the animal heat and all the other processes.

The accessory foods are rather deficient in the soldier's food, and vinegar especially should be used. Robert Jackson very justly insisted on the importance of vinegar as a digestive agent and flavourer, as well, no doubt, as an anti-scorbutic. He remarks on the great use of vinegar made by the Romans, and possibly the comparative exemption which they had from scurvy was due to this.

[1] Some indigestible *cellulose* not reckoned. [2] Taken as *cabbage*.

[3] That the food of the English soldier is deficient, especially for the younger men, is known also from evidence. The late Director-General (Sir James B. Gibson) strongly urged on the authorities the desirability of increasing the ration of meat, and in the report on the recruiting of the army the same point was brought forward. Inquiries among soldiers showed that the recruits and young soldiers could eat much more; though the old soldiers, many of whom had been long accustomed to take spirits, and who had injured their digestive powers by so doing, took less food. There is no doubt that, taking the army through, the ration, especially of meat, is not enough. For further remarks, see "The Soldier's Ration," by F. de Chaumont, *Sanitary Record*, Feb. 5, 1876.

The diet of the soldier on foreign stations is stated under the several headings when it differs materially from that of home service, and the alterations in the diet which should be made under circumstances of great exertions are given in the proper chapter.

In the time of Edward VI. the English soldier's rations during war were—meat 2 ℔, bread 1 ℔, wine 1 pint (Froude).

No scale of diet is laid down for war, and probably it would be fixed at the time, and in view of the possible character of the campaign. The war scale should be very liberal, and every article ought to be issued by the Supply Department. It would be probably a good plan to have the supply under two headings, the "usual" and the "extra" articles, the latter being intended for special occasions, such as forced marches, rapid movements far from the base of supplies, &c. The usual ration ought not to contain less than 375 to 400 grains of nitrogen. The following is suggested as a liberal and varied war ration, which could be easily supplied under ordinary cases:—Bread, $1\frac{1}{4}$ ℔; fresh meat (without bone), 1 ℔; peas or beans, 3 ounces; potatoes and green vegetables, 1 ℔; cheese, 2 ounces; bacon, 2 ounces; sugar, 2 ounces; salt, $\frac{1}{2}$ ounce;[1] pepper, $\frac{1}{20}$ ounce; ground coffee, 1 ounce; tea, $\frac{1}{2}$ ounce; red wine, 10 ounces, or beer, 20 ounces. No spirit ration to be given, except under order from the generals of divisions. The nutritive value of this diet is:—Albuminoids, 5·6 ounces; fats, 3·43; carbo-hydrates, 16·6; salts, 1·37, equal to 410 grains of nitrogen and 5000 of carbon.[2]

Another ration proposed by Deputy Surgeon-General Marston, C.B., is as follows for one week:—Bread, 4 ℔; biscuit, 2 ℔; oatmeal, 1 ℔; rice, 1 ℔; meat, fresh (with bone), 4 ℔; meat, preserved, 2 ℔; bacon, $1\frac{1}{2}$ ℔, or pea-sausage (erbswurst), 2 ℔; cheese, $\frac{3}{4}$ ℔; potatoes or fresh vegetable, 7 ℔ (or dried and preserved, $2\frac{1}{2}$ ℔); sugar, 14 ounces; salt, $3\frac{1}{2}$ ounces; tea, 2 ounces; coffee and cocoa, each $3\frac{1}{2}$ ounces; total weight per man per week, 25 ℔ gross, or, daily, $3\frac{1}{2}$ ℔. The nutritive value daily would be:—Albuminoids, 5·5 ounces; fat, 4·6; carbo-hydrates, 16·5; salts, 1·5; total, 28·1 ounces. These would equal—nitrogen, 385 grains; carbon, 6000 grains; carbon to nitrogen, 15·6 : 1; foot-tons of energy, 4865, available for 380 to 400 of visible work. There is some convenience in the field in arranging for a weekly ration instead of a daily one.

The "extra" articles would be kept in readiness by the Supply Department for occasional issue, viz., salt meat, Australian or New Zealand corned meat, Chicago corned meat, dried meat (such as Hassall's, M'Call's, or Meinert's, or the best market article of the kind), Liebig's extract of meat, pea and beef sausages, biscuits, flour, meat biscuits, rice, lime juice, preserved vegetables, brandy or rum, and vinegar.

This plan supposes that the "usual" scale of diet would be issued to the troops, and the "extra" articles under certain conditions, and under order of the General of the Division.

Bread (which should be well-baked) should be issued as long as possible;[3]

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[1] It may be suggested that chloride and phosphate of potassium, and perhaps a little citrate of iron, might be added to the common salt.

[2] For further remarks see "Military Hygiene," a lecture by F. de Chaumont, *Journal of the United Service Institution*, 1870.

[3] Steam baking ovens have been used in the Autumn Manœuvres, and have been found very good. Field ovens were also built by iron hoops fixed in the ground. Lord Wolseley gives the following plan:—Take a barrel (with iron hoops, if possible), knock out the head, lay it on its side, after scraping a bed for it; cover it with a coating of 6 or 8 inches of thick mud, except at the open end; pile up sand or earth to a thickness of 6 inches over the mud; arrange a flue at the end distant from the open part, through the mud and earth, of 3 inches diameter, to increase the draught when the fire is burning. Form an even surface of well-kneaded mud at the bottom of the barrel; light a fire in the barrel, and keep it alight until

and if biscuit is issued for more than a week, flour or rice should be added to it. When salt meat is issued for several days in succession, vinegar should be given with it. If no vegetables can be obtained, lime juice should be early had recourse to.

The usual alcoholic ration of the troops should be beer or wine, instead of spirits. As all the continental armies issue wine rations in war, there can be no difficulty on the score of transport; and even with beer, though twice as bulky as wine, it is believed that it could be in most cases supplied.

But the issue of red wine instead of spirits is strongly urged.

For rapid expeditions, when transport has to be reduced to the minimum, the use of concentrated and cooked foods is all-important. The men can carry enough for seven or eight days, and are then independent of all base of supply.

Pea and flour sausages, meat biscuits, and dried meat are the best to use; and the issue of cheese and bacon fat, if it can be obtained with these, gives a diet which is fairly nutritious and not disagreeable. The following would be the weight of food which would last a man for a week, and render him independent of the Commissariat during that time:—Biscuit, 2 ℔; pea or flour meat sausages, 4 ℔; dried meat, 2 ℔; sugar, $\frac{3}{4}$ ℔; tea, $\frac{1}{4}$ ℔; cheese, 1 ℔;—total, 10 ℔. That is to say, a weight of 10 ℔, which would be lessening day by day, would, if properly used by the men, carry them through a week's labour, and although, of course, a meagre diet, would yet enable them to do their work. A special emergency ration has been long under consideration.

The extract of meat, as an extra ration, is intended for another purpose. It has a great restorative power, and should be kept for special cases, such as the following:—

1. It is expected the army, after a rapid march, will meet the enemy, and that there will be no time for preparing food. A small quantity of Liebig's extract, merely mixed with 3 or 4 ounces of red wine, will restore strength in a wonderful way; no cooking is required, and ten minutes' time will supply a whole regiment.

2. The force meets heavy weather, and every man is drenched. The issue of Liebig's extract, made into hot soup, and with wine added, will have a very great effect in preventing bad consequences.

3. A forced march has to be made in a very short time, and no fires can be lighted for cooking. Liebig's extract in small tins should be distributed to the men, who should spread it on their biscuits.

4. After action it is invaluable for wounded men, and can be carried about the field and given to the men who cannot be brought into the hospital.

It would be convenient to have the extract carried in cases holding small quantities, so that one pot may be issued to ten or twenty men.

The strength and use will require to be explained.

In war the supply of food is often difficult, but as an army "fights on its belly," the importance of food at critical movements cannot be overrated. The uncertainty of the time of supply, and the difficulty of cooking, often cause the men to be without food for so many hours as to exhaust them greatly, and some actions have been lost, others have remained without good result, from this cause. This can only be avoided by regimental transport

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all the wood is burnt; there will then be a good oven of clay, supported by the iron hoops. When heated for baking, the mouth is closed with boards, or a piece of iron or tin. These ovens were used in the Red River Expedition, and answered admirably.

of condensed and ready-cooked food, which may be used on such emergencies, and given in addition to the usual rations issued by the Supply Departments. The colonel of a regiment would then always be sure that he had the means of keeping up the strength and vigour of his men. The Austrians have tried a plan of cooking, which is intended to obviate one difficulty on the march.[1] A Viennese engineer (Herr Beuerle) has altered Papin's digester in such a way as to make it a convenient cooking utensil, and it is now in use in the Austrian ambulances. It is a doubly conic iron pot covered with a lid, and capable of standing the pressure of five atmospheres; the lid is fastened by screws, and a layer of felt or india-rubber is between it and the rim of the pot, so as to exclude air; in the lid is a ventilating opening, weighted to 2·5 ℔ (Austrian = 3·1 ℔ English), so that it opens when the pressure exceeds one atmosphere. The meat, salt, vegetables, &c., are put into this digester, and it is filled up with water till about 3 fingers' breadth from the top. The amount of water is 1 pint (English) to 1 ℔ of meat (English). This makes so strong a soup that it has to be diluted. The pot with the lid screwed down is put on the fire (three iron supports from which the pot hangs, like a gipsy's kettle, are provided for the field), and as soon as steam is developed, which is known by opening the ventilator a little, the fire is moderated. In an hour and a half the soup is ready. Pots to cook from eight to twenty-five rations are made, and special arrangements are made for cooking potatoes, &c. The plan is, in fact, in principle similar to Warren's compressed-steam boilers, now used in the army, but is simpler.

One advantage in active service of this plan is, that if the troops are surprised, and have to move off their ground before the soup is ready, the pot is simply thrown into the waggon, and at the end of the march the soup is usually found to be ready.[2]

Rations of the French Soldier.[3]

In Time of Peace.

Under the Regulations of 1873, the Government furnishes the meat for the soldiers' rations at about 35 per cent. under market price. This has proved a great advantage for the soldier. The State also furnishes bread (*pain de munition*) and fuel; the white bread (*pain de soupe*), as well as other articles, are bought from the funds of the *ordinaire*, or common fund of the company, battery, or squadron. To this the soldier pays 43 centimes a day, out of 48 that he receives, except in Paris, when his contribution is 51, out of a total of 58. The remaining 5 or 7 centimes he receives in cash.

Infantry of the Line.

If biscuit is issued, 550 grammes (or 19·4 ounces) are given in place of bread. If salt beef is used, 250 grammes (8·8 ounces) are issued, or 200 (7 oz.) of salt pork. Haricot beans form the chief part of the dried vegetables. The following is the authorised scale :—

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[1] Der Beuerle'sche Dampfkochtopf, *Deutsche Militairarztliche Zeitsch.*, 1872, Heft v. p. 215.

[2] In the Crimea, Soyer introduced various portable cooking stoves, but probably the compressed-steam cooking will supersede all others. Soyer also gave several receipts for field cooking, which were found to be very useful. A number of these receipts were printed in 1872 at the Royal Artillery Institution at Woolwich. In case of a war, it would be useful to print some receipts of the same kind, adapted to the particular sort of cooking stove then in use.

[3] *Code des Officiers de Santé*, par Didiot, 1862, pp. 481 *et seq.* Alterations have been made in the scale of diet since 1874; the new scale is given in the text.

	Grammes.	Ounces avoir.
Munition bread,	750	26·4
White bread for soup,	250	8·8
Meat (*uncooked*),	300	10·6
Vegetables (green),	100	3·5
" (dried),	30	1·1
Salt,	15	0·5
Pepper,	2	0·073 = 31 grains.
Total,	1447	51·00

Analysed by the table for calculating diets, and deducting 20 per cent. from the meat for bone, the water-free food of the French infantry soldier is, in ounces and tenths—

	Water.	Albuminoids.	Fats.	Carbohydrates.	Salts.	Water-free Food.
Meat,	6·30	1·26	0·70	...	0·13	2·09
Bread,	14·15	2·82	0·53	17·25	0·45	21·05
Vegetables (taken as cabbage),	3·19	0·01	0·00	0·21	0·02	0·24
Vegetables dried (as peas),	0·16	0·24	0·02	0·58	0·02	0·86
Salt,	...	...	...	...	0·50	0·50
Total,	23·80	4·33	1·25	18·04	1·12	24·74

In Algiers the ration of bread is also 750 grammes, or 26·5 ounces, and 8·8 ounces for soup, or biscuit 643 grammes. The meat is the same; 60 grammes of rice and 15 of salt are issued, and, on the march, sugar, coffee, and ¼ litre of wine.

In time of war discretion is given to the Minister of War and the General Commanding, by the decree of 26th October 1883, to fix and modify the soldiers' rations, so as to suit the circumstances and places where war may be carried on. By the decree of 16th December 1874, soldiers on board ship receive the same rations as the sailors of the navy, which are much more liberal than those allowed by the military regulations.

German Soldier.[1]

The soldier receives his pay every ten days, *i.e.*, three times a month; it amounts to three thalers (or 9 shillings English) per month,[2] or 3 silbergroschen (= 3½ pence nearly) a day. Out of this he has to defray the cost of a warm dinner (*menage*) at the rate of 1¼ silbergroschen (= 1½ penny); and he also receives a mess contribution, varying according to the market prices of food.[3]

The rations in time of peace are divided into the smaller and the larger victualling rations.[4]

[1] From information furnished by Dr Roth, of the Prussian Army (now Surgeon-General, Saxon Army).

[2] Lance-corporals and privates who have engaged themselves to serve a longer term of years receive additional pay—1 thaler (3 shillings) per month.

[3] In the new currency—1 thaler = 3 marks; 1 mark = 100 pfennings; 1 silbergroschen = 10 pfennings.

[4] The Prussian weights are now assimilated to the French; the Prussian pound is = ½ kilogramme or 500 grammes; the loth = 16·66 grammes, or 0·5870 oz. avoir.

	Smaller Ration, in ounces avoir.	Larger Ration for Marches, &c., as supplied from the Military Stores, in ounces avoir.
Bread,	26·50	26·50
Meat (raw),	6·00	8·82
Rice,	3·20	4·22
Or unhusked Barley (groats),	4·21	5·28
Or Peas and beans,	8·22	10·60
Or Potatoes,[1]	53·08	70·5
Salt,	0·87	0·87
Coffee,	0·468	0·468

These would furnish in their best form about the following (oz. avoir.):—

Kind of Ration.	Albuminoids.	Fat.	Carbohydrates.	Salts.	Total Water-free.
Smaller Ration,	4·8	1·1	17·4	1·5	24·8
Larger Ration,	5·7	1·4	18·6	1·6	27·3

Troops, when travelling by railway or steamer, receive an additional pay of 2½ silbergroschen (= 3 pence) per man for refreshments. Should the travelling last longer than 16 hours, the additional pay is doubled.

In Time of War.—The supply of rations for the Germans during the Franco-German war was thus conducted :—

1. During the marches in Germany the men were billeted, and money was paid for their food.

2. Supplies were drawn from the Magazines.

3. Supplies were obtained by requisition when the troops entered France. This last plan was a bad one, as was especially shown in the march to Sedan, where the Germans passed over a country previously nearly exhausted by the French. The principal defect was the great uncertainty and irregularity of the supplies; some corps received too much, others too little, and the hospitals especially, which had not men to send out to get supplies, were particularly badly off. The quality of the food was also often bad; so that, as far as the health of the troops is concerned, the system of supplies by requisition should be as little used as possible. It must be noted, however, here, that the Germans did not pay ready money, which might, perhaps, have attracted better supplies than the system of written vouchers. The magazine supplies were excellent, but occasionally failed in certain articles, such as fresh meat, as a substitute for which the celebrated pea-sausage was issued. But it was found that if the pea-sausage was used too exclusively the men disliked it. In fact, one of the greatest difficulties was the too great uniformity of the food. To do away with this, bacon, preserved and smoked meat, peas and white beans, and potatoes, when possible, were issued as a change of diet. Independent of these extra issues, the daily German ration was as follows, in English weights :—

	Bread,	26½ ounces, or biscuit, 17 ounces.
One of these	Fresh or salt meat,	13 "
	Salted beef or mutton,	9 ounces, or
	Bacon,	5¾ ounces.
	Rice,	4·4 "

[1] 25 per cent. is lost in boiling and peeling; besides, smaller potatoes than the English kind are served out, occasioning still more waste.

One of these {	Barley or groats,	4·4 ounces.
	Peas or beans,	8·8 „
	Flour,	8·8 „
	Potatoes,	3·3 lb.
	Salt,	0·7 ounce.
	Coffee,	0·7 ounce of unroasted, or 1·0 ounce of roasted.

The want of knowledge of cooking was very great, and the addition also of articles to give flavour, as vinegar and spices, would have been much prized. Roth strongly recommends the establishment of a school for cooking, like that at Aldershot.

The bread, owing to the long time it was on transport, was sometimes mouldy.

Austrian Soldier.[1]

In time of peace, receives—bread, 31 oz. avoir.; meat (without bone), 6·6; suet, 0·6; flour (or vegetables in lieu), 2·5; salt, 0·6. To this are added a little garlic, onions, and vinegar. These give about—

	Albuminoids.	Fat.	Carbohydrates.	Salts.	Water-free Food.
In time of peace,	3·7	1·6	17·0	1·0	23·3
In time of war[2] (mean),	4·5	3·2	22·8	1·0	31·5

The amount of the peace ration is much the same as our own. There is too great a preponderance of bread, and there is too great sameness; the fat is in too small a quantity; the nitrogenous substances are too small.

In time of War.—It is difficult to calculate the daily ration, as there is a weekly issue of many substances; the above figures are a mean taken from those cited by Meinert. On four days fresh pork is issued; the total amount being 26 oz., or 6½ oz. daily. On one day, 6 oz. of salt pork; on one day, 6 oz. of beef; and on one day, 6 oz. of smoked bacon; altogether in the week, 44 oz. of meat are issued; and in addition, 1 oz. of butter or fat.

There are also issued per week:—24½ oz. of biscuit, 147 oz. of flour for bread, 29½ oz. of flour for cooking, 5½ oz. of pickled cabbage (sauer kraut), 9 oz. of potatoes, 5½ oz. of peas, and 5 oz. of barley.

Wine, brandy, and beer are also given.

Russian Soldier.[3]

There are 196 meat days and 169 fast days in the year. On the *meat* days meat is given with sehtsehi (cabbage soup) and buckwheat gruel; on the *fast* days the meat is replaced by peas and (occasionally) fish. 42 oz. avoir. of rye bread are issued daily. This is large, but it is probably watery. Meinert[4] calculates the nutrition value as follows, oz. avoir.:—

Albuminoids.	Fat.	Carbohydrates.	Salts.	Water-free food.
5·8	1·0	25·0	2·5	34·3

[1] Kraus, quoted by Roth.
[2] Meinert, *Armee- und Volks-Ernährung*, Berlin, 1880.
[3] For details of this diet, see Dr Oscar Heyfelder's *The Russian Camp at Krasnoe-Selo*, German edition, 1868, or former editions of the present work, or Roth and Lex, *op. cit.*
[4] *Op. cit.*

On the march, $1\frac{3}{4}$ ℔ biscuit ($24\frac{1}{5}$ English oz.) instead of bread. Brandy only on rare occasions, calculated at 135 fluid ounces per year (in 5 oz. rations).

Sepoy Diet.—Dr Goodwin has calculated the diet of a Hindu, such as a Sepoy servant, to consist of 4·387 oz. of albuminoids; 1·278 oz. of fat; 18·584 oz. of carbo-hydrates; and 0·64 oz. of salts—total water-free food, 25·113 oz. It is thus a really better diet than that of the European soldier. The principal articles were—24 oz. of attar (ground wheat), 4 oz. of dāl (pea), and 1 oz. of ghee (butter). In other cases rice is more or less substituted for wheat. The Hindu diet consists of wheat, or of some of the millets (cholum, ragi, cumbu—see *Millets*), rice, leguminosæ (*Cajanus indicus*), with green vegetables, oil, and spices. If any kind of diet of this sort has to be calculated, it can be readily done by means of analysis of the usual foods previously given. For example, a Hindu prisoner at labour in Bengal receives, under Dr Mouat's dietary,[1] the following diet during his working days:—

	Total. oz.	Water. oz.	Album. oz.	Fat. oz.	Starches. oz.	Salt. oz.	Water-free Food.
Rice, ...	20·00	2·0	1·0	0·16	16·64	0·10	17·9
Dāl (a pea, *Cajanus indicus*), .	4·25	0·6	0·9	0·08	2·75	0·12	3·3
Vegetables (reckoned as cabbage),	6·00	5·3	0·1	0·03	0·34	0·04	0·5
Oil, ...	0·33	...	...	0·33	...	...	0·3
Salt, ...	0·33	...	...	...	...	0·33	0·3
Spices, ...	0·33	...	...	...	...	...	...
Total, ...	31·24	7·9	2·0	0·60	19·83	0·59	22·4

In some Bengal prisons, 2 oz. of fish or flesh appear to be also given.

In the Looshai expedition the Sepoys received—rice, 1 ℔; flour, 1 ℔; ghee, 2 oz.; salt, 1·5 oz.[2] The nutritive value, if the ghee is calculated as butter, is 178 grains of nitrogen and 6080 of carbon, which, though deficient in nitrogen, would appear to be a good diet in respect of carbon. Probably some peas were added.

SECTION III.

THE CLOTHING OF THE SOLDIER.

The structure and examination of fabrics have been already given.

Regulations.—No specific instructions are laid down in the *Medical Regulations* respecting clothing, but the spirit of the general sanitary rules necessarily includes this subject also. When an army takes the field, the Director-General is directed to issue a code for the guidance of medical officers, in which clothing is specially mentioned; and the sanitary officer with the force is ordered to give advice in writing to the commander of the forces, on the subject of clothing among other things.

Formerly a certain sum, intended to pay for the clothing of the men, was allotted by Government to the colonels of regiments. This was a relic of

[1] See Mouat's elaborate report, *On the Diet of Bengal Prisoners*, Government Return, 1860, p. 49. The chittack is reckoned as the bazaar chittack, viz. = ·1283 ℔, or about 2 ounces avoir. Some useful information on prison and coolie diets will be found in a memorandum prepared by Surg.-Major I. B. Lyon, F.C.S., Chemical Examiner to the Government at Bombay, May 1877.

[2] *Indian Med. Gazette*, March 1, 1872.

the old system by which regiments were raised, viz., by permitting certain persons to enlist men, and assigning to them a sum of money for all expenses. The colonel employed a contractor to find the clothes, and received from him the surplus of the money after all payments had been made. A discretionary power rested with the service officers of the regiment, who could reject improper and insufficient clothing, and thus the interests of the soldier were in part protected.[1] The system was evidently radically bad in principle, and, since the Crimean war, the Government has gradually taken this department into its own hands, and a large establishment has been formed at Pimlico, where the clothing for the army is now prepared. This system has worked extremely well; the materials have been both better and cheaper, and important improvements have been and are still being introduced into the make of the garments, which cannot fail to increase the comfort and efficiency of the soldier.

At the Pimlico depôt the greatest care is taken to test all the materials and the making up of the articles; the viewers are skilled persons, who are believed to be in no way under the influence of contractors.

In January 1865 a warrant was issued containing the regulations for the clothing of the army, and several other warrants and circulars have since been promulgated. They are now consolidated in the *Regulations for the Supply of Clothing and Necessaries to the Regular Forces*, 1881 (vol. ii., *Revised Army Regulations*).

When a soldier enters the army he is supplied with his kit; some articles are subsequently supplied by Government, others he makes good himself. In the infantry of the line a careful soldier can keep his kit in good order at a cost of about £1 per annum. The following are the articles of the kit supplied to the infantry recruit:—

Clothing.

2 Frocks.	2 Pairs ankle boots (one each half-year).
2 Pairs of trousers.	1 Forage cap and badge.

Necessaries.

2 Flannel shirts.[2]	1 Sponge, pipeclay.
3 Pairs socks (worsted).	1 Razor and case.
1 Pair braces.	1 Hold-all.
1 Pair mitts.	1 Tin of blacking.
1 Hair comb.	1 Blacking brush.
1 Knife (table).	1 Brass brush.
1 Fork.	1 Cloth brush.
1 Spoon.	1 Polishing brush.
1 Mess tin and cover.	1 Shaving brush.
2 Towels.	1 Button brass.
1 Piece of Soap.	1 Kit bag.

The kit is divided[3] into the surplus and the service kit. The former, consisting of 1 frock, 1 pair of socks, 1 shirt, 1 towel, 2 brushes, and such

[1] But this safeguard was not sufficient. Officers are not judges of excellence of cloth; for this it requires special training. As Robert Jackson said sixty years ago: "Soldiers' clothing is inspected and approved by less competent judges than those who purchase for themselves."

[2] By a *Circular*, November 1865, flannel shirts only are ordered to be supplied to the recruit.

[3] *Queen's Regulations*, 1885, section 12, par. 50.

articles for the hold-all as are not wanted, is carried for the men. The service kit is supposed to be carried by the man, either on his person or in his knapsack.

Certain articles are also issued free of expense at stated intervals. For the particulars of these, reference must be made to the *Regulations*, 1881, where they are stated in detail. The following are the articles issued to the Line infantry soldier at home :—

1 helmet and bag, ...	Quadrennially.
1 tunic, ...	Biennially.
1 frock, ...	Annually.
1 pair tweed trousers, ...	Annually.
1 pair tweed trousers, ...	Biennially.
2 pairs of boots, one on 1st April and one on 1st October, ...	Annually.
1 forage cap, ...	Annually.
1 silk sash for sergeants, ...	Biennially.
1 worsted sash for sergeants, . . .	Biennially.
1 greatcoat, ...	Every five years.

In India and the West Indies, and other tropical stations, light clothing of different kinds is used—drill trousers and calico jackets, or in India complete suits of the khaki, a native grey or dust-coloured cloth, or tunics of red serge and very light cloth. The khaki is said not to wash well, and white drill is superseding it. The English dress is worn on certain occasions, or in certain stations. Formerly the home equipment was worn even in the south of India; but now the dress is much better arranged, and differences of costume for different places and different times of the year are also being introduced.

During campaigns extra clothing is issued according to circumstances. In the Crimea the extra clothing was as follows for each man :—

2 Jersey frocks.	1 Cholera belt.
2 Woollen drawers.	1 Fur cap.
2 Pairs woollen socks.	1 Tweed lined coat.
2 Pairs woollen mitts.	1 Comforter.

To each regiment also a number of sheepskin coats was allowed for sentries.

The *Regulations* for 1881 order the following articles of clothing to be issued to each man proceeding on active service in cold, temperate, or hot climates :—

1. *In cold climates*—

Sheepskin coats (for 100 men),	8	Drawers, flannel (per man) pairs,	2
Fur caps (per man), .	1	Cholera belts, flannel, . ,,	2
Woollen comforters, ,, . .	1	Mittens, lined with lambskin or fur, . . . ,,	1
Jerseys, blue, ,, . .	1	Pilot coats, each mounted man,	1
Boots, knee, brown leather, pairs,	1		
Stockings, woollen, ,,	2		

2. *In temperate climates*—

Cholera belts, when not included in the voyage kit, . . .	2	Waterproof capes (for 100 men),	10
		Watch coats, ,,	3

3. *In tropical climates*—

White helmets (per man),	1
Frock coats, of serge or tartan, when not supplied as ordinary clothing of these climates,	1
Cholera belts, of flannel, when not part of the sea kit,	2
Capes, waterproof (for 100 men),	10

For India, a drill frock, drill trousers, and a white cap cover are issued.

SECTION IV.

ARTICLES OF CLOTHING.

1. *Underclothing*, viz., vests, drawers, shirts, stockings, flannel belts, &c.

The soldier, as a rule, wears as underclothing only a shirt and socks. He is obliged to have in his kit two shirts. There has been much discussion as to the respective merits of cotton and flannel shirts. Almost all medical officers prefer the latter, but their cost, weight, difficulty of cleaning, and shrinking in washing, have been objections to its general adoption. General Sir A. Herbert solved the difficulty by issuing a shirt which is partly wool, partly cotton; it is lighter and cheaper than wool, as durable as cotton, and does not shrink in washing. It is of soft even texture, and weighs 19 ounces. Under the microscope, Dr Parkes counted from 45 to 47 per cent. of wool.

In time of war, shirts may be partially cleaned in this way:—The soldier should wear one and carry one; every night he should change; hang up the one he takes off to dry, and in the morning beat it out and shake it thoroughly. In this way much dirt is got rid of. He should then carry this shirt in his pack during the day, and substitute it for the other at night. If in addition great care is taken to have washing parades as often as possible, the difficulty of cleaning would be avoided.

For hot countries the common English flannels are much too thick and irritating; flannel must be exceedingly fine, or what is perhaps better, merino hosiery, which contains from 20 to 50 per cent. of cotton, could be used. The best writers on the hygiene of the tropics (Chevers, Jeffreys, Moore) have all recommended flannel.

The soldier wears no drawers, but in reality it is just as important to cover the legs, thighs, and hips with flannel as the upper part of the body. Drawers folding well over the abdomen form, with the long shirt, a double fold of flannel over that important part, and the necessity of cholera belts or kamarbands is avoided. Cholera belts are made of flannel, and fold twice over the abdomen.

The soldiers' socks are of worsted; they should be well shrunken before being fitted on. It has been proposed to divide the toes, but this seems an unnecessary refinement. It has been also proposed to do away with stockings altogether, but with the system of wearing shoes, it is difficult to keep the feet perfectly clean. The boots get impregnated with perspiration. Some of the German troops, instead of stockings, fold pieces of calico across the foot when marching; when carefully done, this is comfortable, but not really better than a good sock kept clean.

2. *Outer Garments.*—The clothes worn by the different arms of the service, and by different regiments in the same branch, are so numerous and diverse that it is impossible to describe them. In many cases taste, or parade, or fantasy simply, has dictated the shape or the material. And diversities of this kind are especially noticeable in times of peace. When war comes with

its rude touch, everything which is not useful disappears. What can be easiest borne, what gives the most comfort and the greatest protection, is soon found out. The arts of the tailor and the orders of the martinet are alike disregarded, and men instinctively return to what is at the same time most simple and most useful. It will be admitted that the soldier intended for war should be always dressed as if he were to be called upon the next moment to take the field. Everything should be as simple and effective as possible; utility, comfort, durability, and facility of repair are the principles which should regulate all else. The dress should never be encumbered by a single ornament, or embarrassed by a single contrivance which has not its use. Elegant it may be, and should be, for the useful does not exclude, indeed often implies, the beautiful, but to the eye of the soldier it can be beautiful only when it is effective.[1]

Head-Dress.—The head-dress is used for protection against cold, wet, heat, and light. It must be comfortable; as light as is consistent with durability; not press on the head, and not to be too close to the hair; it should permit some movement of air over the head, and therefore openings, not admitting rain, must be made; it should present as little surface as possible to the wind, so that in rapid movements it may meet the least amount of resistance. In some cases it must be rendered strong for defence; but the conditions of modern war are rendering this less necessary.

As it is of great importance to reduce all the dress of the soldier to the smallest weight and bulk, it seems desirable to give only one head-dress, instead of two, as at present. Remembering the conditions of his life, his exposure, and his night-work, the soldier's head-dress should be adapted for sleeping in as well as for common day-work. Another point was brought into notice by the Crimean War: in all articles of clothing it greatly facilitates production, lessens expense, and aids distribution if the different articles of clothing for an army are as much alike as possible; even for the infantry, it was found difficult to keep up the proper distribution of the different insignia of regiments.

Head-Dress of the Infantry.—The present head-dresses are the bearskin caps for the Guards, a smaller and rather lower kind of seal-skin for Fusiliers, the Highland bonnets and shakoes for the Highland regiments, and helmets for the Artillery, Engineers, and Line, and forage caps for all. The bearskin weighs 37 ounces; the Infantry helmet, made of cork and cloth, $14\frac{1}{4}$ ounces. It is for the professional soldier to decide if the rapid movements and the necessity of cover in modern war are compatible with the retention of the bear-skin. If not, no one would wish to retain it on sanitary grounds; it is heavy, hot, gives little shelter from rain, and opposes a large surface to the wind.

The Glengarry Scotch cap, now adopted as the forage cap of the army, is very soft and comfortable, presses nowhere on the head, has sufficient height above the hair, and can be ventilated by openings if desired; it cannot be blown off; it can be carried at the top of the head when desired in hot weather, or pulled down completely over the forehead and ears in cold. Unfortunately, either to save cloth or from some idea of smartness, it is now being made so small that its advantages are imperilled, as it cannot be drawn down over the head.

Head-Dress of the Cavalry.—The Horse Artillery and Cavalry carry helmets and caps of different kinds.

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[1] *La tenue, dans laquelle le militaire est prêt à marcher à l'ennemi, est toujours belle.*—Vaidy.

The shape of the helmet in the Guards and heavy Dragoons is excellent. It is not top-heavy; offers little surface to the wind; and has sufficient but not excessive height above the head. The material, however, is objectionable. The metal intended for defence makes the helmet very hot and heavy; and the helmet of the Cavalry of the Guard (Life Guards and Horse Guards) weighs 55 ounces avoir.; that of the Dragoon Guards, 39 ounces (in 1868). But as every ounce of unnecessary weight is additional unnecessary work thrown on the man and his horse, it is very questionable if more is not lost than is gained by the great weight caused by the metal. Leather is now often substituted in some armies, where the cavalry helmets are being made extremely light.

The Lancer cap weighs $29\frac{1}{2}$ ounces; the Hussar, $28\frac{1}{2}$ ounces.[1] Both are dresses of fantasy. The Lancer cap, except for its weight, is the better of the two; is more comfortable; shades the eyes; throws off the rain better; and offers less resistance to moving air than the Hussar cap.

In Canada a fur cap is used, with flaps for the ears and sides of the face and neck.

In India many contrivances have been used. Up to the year 1842 little attention seems to have been paid to the head-dress of the infantry, and the men commonly wore their European forage caps. In 1842 Lord Hardinge issued an order that white cotton covers should be worn over all caps; subsequently a flap to fall down over the back of the neck was added. The effect of the cotton cover is to reduce the temperature of the air in the cap about 4° to 7° Fahr. Although a great improvement, it is not sufficient.

Bamboo wicker helmets, covered with cotton and provided with puggeries, are now used; they are light (13 oz.), durable, not easily put out of shape, and cheap. The rim is inclined, so as to protect from the level rays of the sun. The pith, or "Sola" hats, appear to be decidedly inferior to the wicker helmets; and men have had sunstroke while wearing them.

In the French infantry the shako is now made of leather and pasteboard, and is divested of all unnecessary ornament, so as to be as light as it can be. It comes well back on the head, being prolonged, as it were, over the occipital protuberance.

In Algeria, the Zouaves, Spahis, and Tirailleurs wear the red fez, covered with a turban of cotton. In Cochin-China the French have adopted the bamboo wicker helmet of the English.

The natural hair of the head is a very great protection against heat. Various customs prevail in the East. Some nations shave the head, and wear a large turban; others, like the Burmese, wear the hair long, twist it into a knot at the top of the head, and face the sun with scarcely any turban. The Chinaman's tail is a mere mark of conquest. The European in India generally has the hair cut short, on account of cleanliness and dust. A small wet handkerchief, or piece of calico, carried in a cap with good ventilation, may be used with advantage, and, especially in a hot land-wind, cools the head greatly.

Coat, Tunic, Shell-Jacket, &c.—The varieties of the coat are numerous in the army; and there are undress and stable suits of different kinds. The infantry now wear the tunic, which is a great improvement over the old cut-away coatee. It is still, however, too tight, and made too scanty over the hips and across the abdomen. A good tunic should have a low collar, and be loose round the neck. The *stock* is now abolished, a tongue of leather being substituted where the collar of the tunic is hooked in front. The

[1] *Soldier's Pocket-Book*, p. 17.

tunic should also be loose over the shoulders (so as to allow the deltoid and latissimus the most unrestricted play)[1] and across the chest. It should come well across the abdomen, so as to guard it completely from cold and rain; descending loosely over the hips, it should fall as low over the thighs as is consistent with kneeling in rifle practice, *i.e.*, as low as it can fall without touching the ground. Looking not only to the comfort of the soldier, but to the work and force required of him, it is a great mistake to have the tunic otherwise than exceedingly loose. A loose tunic, a blouse in fact, is in reality a more soldier-like dress than the tight garment, which every one sees must press upon and hinder the rapid action of muscles. The tunic should be well provided with pockets, not only behind, but on the sides and in front; the pockets being internal, and made of a very strong lining. In time of war, a soldier has many things to carry; food, extra ammunition sometimes, all sorts of little comforts, which pack away easily in pockets. If the appearance is objected to, they need not be used in time of peace; but with a loose dress they would not be seen.

A great improvement was made by General Herbert. The old shell-jacket was done away with, and a loose frock substituted.

In India the tunic is made loose, and of thin material.

Waistcoats.—No waistcoats are worn in the British army, but they ought to be introduced.[2] A long waistcoat with arms is one of the most useful of garments; it can be used without the tunic when the men are in barracks or on common drill. Put on under the tunic, it is one of the best protections against cold. At present the men are obliged to wear tight coats, and, having nothing under them, line them with flannel and wadding. In winter and summer they often wear the same dress, although the oppression in the summer is very great. If the tunic were made very loose, of some light material, and if a good short Jersey or Guernsey frock were allowed to be worn at the option of the men, the men would have cool dresses in summer, warm in winter, and the thin tunic would be more comfortable in the Mediterranean and subtropical stations.

Trousers.—Formerly the army wore breeches and leggings; but shortly before or during the Peninsular war trousers were introduced. The increased comfort to the soldier is said to have been remarkable; the trousers, indeed, protecting the leg quite down to the ankle, seems to be as good a dress as can be devised, if it is made on proper principles, viz., very loose over the hips and knees, and gathered in at the ankle, so that merely sufficient opening is left to pass the foot through. The much-laughed-at pegtop trousers seem to be, in fact, the proper shape. In this way the whole leg is protected, and the increased weight given by the part of the trousers below the knee is a matter of no consequence.

The trousers are supported either by braces or a belt. If the latter be used, it should be part of the trousers, should fit just over the hip, and not go round the waist. It must be tight, and has one disadvantage, which is that in great exertion the perspiration flowing down from above collects there, as the tight belt hinders its descent; also, if heavy articles are carried in the pocket, the weight may be too great for the belt. Braces seem, on the whole, the best.

Trousers should be made with large pockets, on the principle of giving the men as much convenience as possible of carrying articles in time of war.

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[1] This cannot occur if epaulets are worn; and it is to be hoped nothing will ever occur to bring in again the use of the so-called ornaments.

[2] A waistcoat was introduced some time ago, but has since been unfortunately withdrawn again.

In India, trousers are made in the same fashion as at home, but of drill or khaki cloth, or thin serge—an excellent material, especially for the northern stations.

Leggings and Gaiters.—Formerly long leggings reaching over the knees, and made of half-tanned leather, were used. They appear not to have been considered comfortable, and were discarded about sixty years ago. Short gaiters were subsequently used for some time, but were finally given up, and for several years nothing of the kind was worn. After the Crimean war Lord Herbert introduced for the infantry short leather leggings, six inches in height, and buttoning on the outside. These were not of good length or shape, and have now been superseded by leggings which come more up to the knee, and are much more serviceable.

In some of the French regiments a gaiter of half-dressed hide comes up to just below the knee; short calico or linen gaiters are worn by other corps; a flap comes forward over the instep. The calico gaiters have been much praised, but they soon get saturated with perspiration, thickened in ridges, and sometimes irritate the skin. On the other hand, leather gaiters, if not made of good leather, lose their suppleness, and press on the ankles and instep.

A great advantage of gaiters and leggings is, that at the end of a march they can be at once removed and cleaned; but, on the whole, if suitable leather could be fixed at the bottom of trousers, they might perhaps be abandoned.

Shoes and Boots.—In the action of walking the foot expands in length and breadth; in length often as much as $\frac{1}{10}$th, in breadth even more. In choosing shoes this must be attended to. The shoemaker measures when the person is sitting, and as a rule allows only $\frac{1}{24}$th increase for walking. Ankle boots, weighing 40 to 42 ounces, are now worn by the infantry: the cavalry have Wellingtons and jackboots. The jackboots of the life guards weigh (with spurs) 100 ounces avoir. Shoes cannot be worn without gaiters. Ankle boots are preferable; in the English army they are now made to lace, and are fitted with a good tongue. Great attention is now paid at Pimlico to the shape and make of the boot, and the principles laid down by Camper, Meyer, and others, are carefully attended to. There are eight sizes of length and four of breadth, making thirty-two sizes in all. The boots are made right and left. The heel is made very low and broad, so that the weight is not thrown on the toes, the gastrocnemii and solei can act, which they cannot do well with a high heel, and there is a good base for the column which forms the line from the centre of gravity, and the centre of gravity is kept low; the inner line of the boot is made straight, so as not to push outwards the great toe in the least degree, and there is a bulging over the root of the great toe to allow easy play for the large joint. Across the tread and toes the foot is made very broad, so that the lateral expansion may not be impeded; the toes are broad. Great care is taken in the inspection of the boots, the order of inspection being—1*st*, the proof of the size, which is done by standard measure; 2*nd*, the excellence of the leather, which is judged of by inspection of each boot, and by selecting a certain number from each lot furnished by a contractor, and cutting them up; if anything wrong is found, the whole lot is rejected; 3*rd*, the goodness of the sewing; there must be a certain number of stitches per inch (not less than eight for the upper leathers), a certain thickness of thread, and the thread must be well waxed. The giving up of boots is generally owing to the shoemaker using a large awl and thin unwaxed thread, with as few stitches as possible; the work is thus easier to him, but the thread soon rots.

The Germans are now introducing a long boot, with a slit down the centre; it can be worn under the trousers, or at pleasure outside, as the

slit opens, and can then be laced. A somewhat similar boot was invented by the late Major Sir W. Palliser.

Considering the great injury inflicted on the foot by tight and ill-made boots, by which the toes are often distorted and made to override, and the great toe is even dislocated and ankylosed, it is plain that the increased attention lately excited on this point is not unnecessary. The compression of children's feet by the tight leather shoes now made is extremely cruel and injurious. It may, indeed, be asserted that the child's foot would be better if left altogether unclothed, and certainly we see no feet so well modelled as the children of the poor, who run about shoeless. In the case of the soldier, too, who has in many campaigns been left shoeless, and has greatly suffered therefrom, it is a question whether he should not be trained to go barefooted. The feet soon get hard and callous to blows, and cleanliness is really promoted by having the feet uncovered, and by the frequent washings the practice renders necessary. After being unworn for some time, shoes that previously fitted will be found too small, on account of the greater expansion of the foot, and this is itself an argument against the shoe as commonly worn.

The sandal in all hot countries is much better than the shoe, and there is no reason why it should not be used in India for the English soldier as it is by the native; the foot is cooler, and will be more frequently washed. For all native troops, negroes, &c., the sandal should be used, and the boot altogether avoided. In campaigns it is most important to have large stores of boots at various points, so that fresh boots may be frequently issued, and worn ones sent back for repair. Soldiers ought to be trained to repair their own boots.[1]

Greatcoat and Cloak.—In the cavalry, cloaks, with capes which can be detached, are carried. They are large, so as to cover a good deal of the horse, and are made of good cloth; the weight is about 5 ℔ to 6 ℔ for the cloak, and 2½ ℔ to 3 ℔ for the cape. The infantry wear greatcoats weighing from 5 ℔ to 6 ℔.[2] They are now made of extremely good cloth, are double-breasted, and are as long as can be managed. They are not provided with pockets at the back, which is a serious omission, and they also should have loops, so that the flaps may be turned back if desired. They are too heavy, and absorb a great deal of wet, so that they dry slowly. General Eyre's Committee on Equipments recommended a lighter greatcoat, and in addition a good waterproof cape. The suggestion seems to be a very good one.[3] A hood might also be added with advantage. In countries with cold winds they are a great comfort. Or the Russian bashlik might be introduced; it is a most useful covering for cold and windy countries.

The greatcoat is perhaps the most important article of dress for the soldier. With a good greatcoat, Robert Jackson thought it might be possible to do away with the blanket in war, and if india-rubber sheets were used this is perhaps possible. In the Italian war of 1859 the French troops left their

[1] It may be worth while to give a receipt for making boots impermeable to wet. Dr Parkes tried the following and found it effectual:—Take half a pound of shoemaker's dubbing, half a pint of linseed oil, half a pint of solution of india-rubber (price 3s. per gallon). Dissolve with gentle heat (it is very inflammable), and rub on the boots. This will last for five or six months; but it is well to renew it every three months. At a small expense the boots of a whole regiment could be thus mado impermeable to wet. *Army Circular*, clause 66, 1875, directs—(1) That boots are to be blackened with three coats of ordinary blacking, instead of other substances. (2) Boots or shoes in store are to be dubbed, or have neat's-foot oil applied to uppers, at least once in four months.

[2] The following are the exact weights of three—one largo size, one medium, and one small; the weights were 6 ℔ 3 ounces, 5 ℔ 9 ounces, and 5 ℔ 8 ounces. Lord Wolseley gives the weights as 4 ℔ 12 ounces for the coat, and 1 ℔ 5 ounces for the cape.

[3] Para. 47, sect. viii. *Regulations for Clothing*, directs the issue of a waterproof coat, leggings, wrappers, sou'wester caps, &c., for certain duties.

tunics at home, and campaigned in their greatcoats, which were worn open on the march.[1]

In countries liable to great vicissitudes of temperature, and to sudden cold winds, as the hilly parts of Greece, Turkey, Affghanistan, &c., a loose, warm cloak, which can be worn open or folded, is used by the inhabitants, and should be imitated in campaigns. It is worthy of remark, that in most of these countries, though the sun may be extremely hot, the clothes are very warm.

In very cold countries, sheepskin and buffalo-hide coats, especially the former, are very useful. No wind can blow through them; in the coldest night of their rigorous winter the Anatolian shepherds lie out in their sheepskin coat and hood without injury, though unprotected men are frozen to death. In Bulgaria, the Crimea, and other countries exposed to the pitiless winds from Siberia and the steppes of Tartary, nothing can be better than coats like these.[2]

SECTION V.

WEIGHTS OF THE ARTICLES OF DRESS AND OF THE ACCOUTREMENTS, AND ON THE MODES OF CARRYING THE WEIGHTS.

The following tables give the weights of all the articles used by a heavy cavalry regiment, an hussar regiment, and the infantry of the line. The weights carried by the artillery are much the same as those of the cavalry. The weights of the helmets and jackboots of the life and horse guards have been already mentioned. The cuirass weighs 10 lb 12 oz.; it rests a little on the sacrum and hip, and in that way is more easily borne by the man. With these exceptions, the weights may be considered nearly the same as those of the heavy dragoons. The uniform and equipment of the guards and cavalry are at present under consideration, and may be changed.

Cavalry.

The weight of the accoutrements and equipment is in great part carried by the horse. The cloak, when not worn, is carried in a roll over the shoulder, or sometimes round the neck, or in front on the horse.

Private in 6th Dragoon Guards.—Weights in Marching Order (Jan. 1872).

Articles.	lb.	oz.	Articles.	lb.	oz.
			Brought forward, .	112	0
Carbine, ...	6	8	Blanket, ...	4	4
Sword-belt and sword, . .	5	8	Heel Ropes, ...	1	8
Pouch-belt and pouch, . .	1	8	,, Pegs, ...	2	2
Cloak and cape, . . .	10	8	Shackles, ...	0	10
Valise completely packed, .	15	0	Collar Shank, ...	0	13
Saddle complete, . . .	47	8	Wellington boots and spurs, .	2	10
Sheepskin, corn-sack, and nose-bag,	8	8		123	15
Man's clothing (which includes a complete set of undercloth-ing, helmet without plume, tunics, pants, haversack, gauntlets, knee-boots, and spurs),	17	0	Average weight of man (naked),	161	0
			Total, .	284	15
Carry forward, .	112	0	Or 20 stone and 5 lb (nearly).		

[1] Cloth may be made waterproof by the following simple plan:—Make a weak solution of glue, and while it is hot add alum in the proportion of one ounce to two quarts; as soon as the alum is dissolved, and while the solution is hot, brush it well over the surface of the cloth, and then dry. It is said that the addition of two drachms of sulphate of copper is an improvement.

[2] Sheepskin bags, with the wool inside, were much used by the French troops during the defence of Paris, in the winter of 1870-71.

Weights of Men's Clothes, Necessaries, &c., 10th Royal Hussars (1869).[1]

No.	Articles.	lb.	oz.	No.	Articles.	lb.	oz.
1	Tunic,	3	0		Brought forward,	32	5¼
1	Busby, plume, and lines,	1	13¾	1	Hair-comb,	0	0½
1	Pair leather overalls and straps,	3	6	2	Pairs drawers, each 13¾ oz.,	1	11½
1	Pair cloth do. do.,	2	7½	2	Pairs gloves, each 7¼ oz.,	0	14½
1	Stable-jacket,	1	15½	Or 2	Pairs cotton socks, each sock 2¼ oz.,	0	9
1	Forage-cap,	0	5	4	Brass paste,	0	3½
1	Valise,	2	7	1	Hold-all,	0	4
1	Cloak, 5 lb 8½ oz.; cape, 2 lb 6 oz.	7	14½	1	Horse-rubber,	0	11
1	Pair boots,	3	0¼	1	Knife, fork, and spoon,	0	4½
1	,, spurs,	0	5¼	1	Pipeclay and sponge,	0	2
1	,, highlows,	3	8	1	Razor,	0	2½
1	Stable bag,	0	6	3	Shirts, each 14½ oz.,	2	11½
1	Pair braces,	0	3¾	1	Button brass,	0	1¾
1	Button-brush,	0	1½	1	Stock,	0	1½
1	Cloth ,,	0	3½	2	Towels, 7¾ oz. each,	0	15½
1	Hair ,,	0	2¾	1	Stable trousers,	1	5
1	Brass ,,	0	2¾	2	Flannel jackets, each 11 oz.,	1	6
1	Lace ,,	0	1	1	Oil tin,	0	2½
1	Shaving ,,	0	1¼	1	Pair foot-straps,	0	0½
2	Shoe ,,	0	7½	1	Mess-tin and strap,	1	1½
1	Tin blacking,	0	4½	1	Account-book,	0	1½
	Carry forward,	32	5¼			45	3½

Weights of Saddlery, 10th Royal Hussars.

Articles.	lb.	oz.	Articles.	lb.	oz.
Saddle-tree,	6	5½	Brought forward,	45	13¾
,, seat,	1	6½	Shabraque,	4	6½
Pair flaps,	2	8½	Numnah,	2	11¼
,, pannels,	4	6½	Corn-sack,	1	11½
Girth-tub,	0	6½	Nose-bag,	1	1½
Girth-leathers,	1	1½	Horse-brush,	0	11
Stirrup-irons,	1	11½	Curry-comb,	0	11
,, leathers,	1	3½	Sponge,	0	2
Crupper,	0	14½	Hoof-picker,	0	1¾
Breastplate,	1	4¼	Scissors,	0	3½
Surcingle,	0	15	Horse-log,	1	3¼
Set of baggage-straps,	0	9¼	Haversack,	0	9
,, cloak-straps,	0	9½	Carbine,	6	9
Pair wallets,	1	14½	Pouch-belt, 11¼ oz.,		
Pair shoe-cases and straps,	1	4	Pouch, 12½ oz.,	3	8¼
4 Horse shoes and nails,	4	9	20 rounds ammunition, 32½ oz.,		
New carbine bucket,	2	13½	Wrist-belt, &c., 1 lb 1 oz.,		
Bridle-bit and head-stall,	2	2	Sabretash and slings, 1 lb 5½ oz.,	7	0½
Bridoon-bit and reins,	1	2	Sword, 4 lb 10 oz.,		
Curb-chain,	0	3¾		76	7¾
Bit-reins,	0	10½			
Head-collar,	1	11½	Weight of equipments,	121	11¼
Collar-chain,	1	12½			
Skeepskin,	4	4			
Carry forward,	45	13¾	Total weight of Hussar[2] with all his equipments,	259	6¼ or 18½ st.[3]

[1] Since this date, the only change is the substitution of long boots for booted overalls; but it is uncertain if this change will be permanent.

[2] Average weight and height of the men in these two cavalry regiments—

	Height. ft.	in.	Weight (naked). lb.	oz.
5th Dragoon Guards,	5	9¼	161	0
18th Hussars,	5	7¼	137	11

[3] Lord Wolseley gives the total weight as 18 st. 5 lb 9½ oz., or 257 lb 9½ oz.; he allows, however, 10 st. 4 lb for the man (=144 lb). The new pattern saddle will be about 4 lb lighter. The weights will still be much too great.

Infantry.

The artieles of the infantry soldier's kit have been already noted. The kit is divided into the service and the surplus kit, the latter being always earried for, and not by, the man. The serviee kit eonsists of the clothes he wears, and of some duplieate artieles and other neeessaries.

The following weights are given by Lord Wolseley:[1]—

	When Valise is worn.		When Valise is not worn.	
	lb.	oz.	lb.	oz.
Clothes in wear,	12	4	12	4
Accoutrements (1882),	4	0	4	0
Arms,	10	9	10	9
Ammunition (70 rounds),	8	0	8	0
Mess-tiu, complete,	1	9	1	9
Haversack,	0	4	0	4
Water-bottle,	1	1	1	1
Balance of day's rations, including tea in water-bottle,	2	0	2	0
Knife and lanyard,	0	6	0	6
Field-dressing,	0	2	0	2
Total,	40	3	40	3
Valise (1882 pattern),	3	0		
In the Valise.				
Reserve rations (sausage), say,	0	12	0	12
Oil-bottle and grease-pot, full,	0	6½	0	4
Towel and soap,	0	8½	0	8½
Brush, clothes,	0	5		
Hold-all, fitted (housewife, comb, fork, and spoon),	0	6½		
Pocket ledger,	0	2	0	2
Belt, flannel,	0	7		
Night-cap, woollen,	0	3	0	3
Flannel shirt,	1	1		
Socks (1 pair),	0	5	0	5
Shoes, canvas,	1	4		
Cape,	1	5		
Greatcoat,	4	12	4	12
Small waterproof sheet,			0	6
	11	13	7	4
Total weight carried by the soldier,	55	0	47	7

In time of war it is most important to have the soldier as little weighted as possible. The long and rapid marehes whieh have so often decided wars have never been made by heavily-laden men. The health also suffers. It is of national importanee that the soldier should be as healthy and as effieient as possible, as the fate of a nation may be staked on the prowess of its army.

The line whieh the weight of his neeessaries should not exeeed should be drawn with the utmost eare; if his health suffers more by earrying some extra pounds of weight than it benefits by the eomfort the artieles give, why load him to his eertain loss? The overdoing the neeessaries of the soldier has always been a fault in our army; Robert Jaekson notieed it seventy years ago. "It is a mistake," he says, "to multiply the equipment of the soldier with a view of adding to his eomfort."

[1] *Op. cit.*, p. 29.

The weight of the clothing, equipment, and kit of the Medical Staff Corps is as follows:—

	lb.	oz.
Clothes on the person, including helmet and leggings, . .	10	9
Greatcoat and cape, ...	5	13
Extra kit and small articles, ...	8	2
Valise with straps, belt, mess-tin, haversack, and black bag, .	8	1
Water-bottle (new pattern) with water, ...	2	9
Field companion, complete, ...	9	13
Water-bottle for ditto, with water, ...	5	12
Total, .	50	11

The valise equipment proposed by General Eyre's Committee, and now adopted for the army, possesses great facilities for carrying these articles, as will be presently noticed.

This committee also recommended that, instead of the squad-bag for 25 men, each man shall have a separate canvas bag for his surplus kit, as is now provided on board ship. In time of peace this would be carried for him, as the squad-bag is at present; in time of war it would be left at home.

It is of great moment to give each man a bag for surplus kit to himself. It encourages the men to take care of their things, and enables them to pack them comfortably. Each man is now supplied with a kit-bag.

It may be interesting to give the weights of the various articles carried by the infantry soldier of the French, Prussian, and Russian armies.

Morache[1] gives the total weight of the French infantry soldier's war outfit and equipment as something over 30 kilogrammes, or nearly 67 ℔. This (1885) is rather less than it was formerly.

The German infantry soldier carries the following weights:[2]—

Clothing on the person (with gloves), not including helmet,	10	12½
Armament and equipment (including helmet, water-bottle (full), coffee-mill, and trenching tools), ...	31	5
Pack, with extra kit, &c., and reserve ammunition, . .	19	13½
Greatcoat and straps, ...	5	11
Rations, ...	7	3½
Total, ...	74	13½

Some of the articles are not always carried by the same man, such as the hatchet, spade, and coffee-mill, so that the weight may be lessened to 66 ℔ —average weight carried, 66 ℔ to 71 ℔. The shako of the riflemen and sharpshooters is about 3½ oz. lighter than the infantry helmet. The Mauser rifle weighs 10 ℔ and the bayonet 1 ℔ 8½ oz.

The Russian soldier carries 70½ ℔, the Austrian 60 ℔, and the Italian 75 ℔; the mean of European armies being 66 ℔.

The mean weight of the rifles[3] carried by European infantry is 9 ℔ 6 oz.; of the bayonet, 1 ℔ 2½ oz.; and of each cartridge, 1⅓ oz.

SECTION VI.

CARRIAGE OF THE NECESSARIES AND ARMAMENT.

The equipment of the cavalry soldier is in great part carried by the horse; but apparently the mode in which the cavalry valise is arranged is not comfortable to the men. The total weight carried by the horse appears

[1] *Op. cit.* [2] Roth and Lex, *op. cit.*, Bd. iii. (1877), p. 110.
[3] This will probably be altered by the introduction of magazine rifles.

also to be large. A soldier has personal and horse equipments equal to nearly his own weight. Without pronouncing on the necessity of this, it is a fact that in light-cavalry regiments the horse now carries nearly 19 stone weight, although the rider is on an average under 10 stone.

In the case of the infantry soldier, who carries the weights himself, the greatest care is necessary to place them in the manner least likely to detract from his efficiency or to injure his health. If it were possible to let a man, in European countries, carry nothing but his armament and water-bottle, as in India, much more work would be got out of him, longer marches would be made, and he would show greater endurance on the day of action. But such an arrangement is impossible, as transport could not be provided, and the alternative of leaving a man without his necessaries is not to be thought of. But it cannot be too strongly impressed on all commanding officers that every ounce of weight saved is a gain in efficiency. The Prussians, in the war of 1866, obtained wagons whenever they could to carry the knapsacks, and the comparison between the condition of the men thus relieved and those who could not be so, was striking.[1] A change of opinion also must be brought about in the army on a very material point. Some officers believe that, as the men must carry weights in war, they ought to carry them on all occasions during peace, so that the men may be accustomed to them; and they attempt to strengthen their position by referring to the custom of the Romans, who exercised their men in peace with heavier weapons than those used in war. But this example is not applicable. A man should be exercised in the highest degree in any way which may develop his muscles and improve the circulation through his lungs and heart. Any amount of muscular exertion (within, of course, reasonable limits), any degree of practice with weapons, must be good as long as his body is unshackled; but if he is loaded with weights, and especially if the carriage of the weights at all impedes the action of the lungs and heart, then the very exertion which in other circumstances would benefit him must do him harm. The soldier must carry weights sometimes, but it should be a rule not to carry them when he has no immediate need of the various articles. The aim should be the cultivation of the breathing power of his lungs and the power of his muscles to an extent which will enable him to bear his weights, at those times when he must carry them, more easily than if, on a false notion of accustoming him to them, he had been obliged to wear them on all possible occasions.

Sufficient practice with the weights to enable a man to dispose them comfortably, and to make him familiar with them, should of course be given; but a very short teaching will suffice for this.

The weights which an infantry soldier has to carry have already been stated; the mode of disposing of them has now to be considered.

Weights are most easily borne when the following points are attended to:—

1. They must lie as near the centre of gravity as possible. In the upright position the centre of gravity is between the pelvis and the centre of the body, usually midway between the umbilicus and pubis, but varying of course

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[1] See Mr Bostock's able Report in the *Army Medical Reports*, vol. vii. p. 359.

Dr Parkes quotes a letter from a Prussian officer, high in rank, and certain to know the fact, stating that the difference in the health of the Prussian soldiers who carried the knapsacks in the Bohemian marches in 1866, and those who did not, was remarkable. The men who had not carried their packs, though they had not had the comfort of their necessaries, were fresh and vigorous and in high spirits; those who had carried them, on the other hand, were comparatively worn and exhausted. And this was with the best military knapsack then known.

with the position of the body; a line prolonged to the ground passes through the astragalus just in front of the os calcis. Hence weights carried on the head or top of the shoulder, or which can be thrown towards the centre of the hip bones, are carried most easily, being directly over the line of the centre of gravity. When a weight is carried away from this line the centre of gravity is displaced, and, in proportion to the added weight, occupies a point more or less distant from the usual side, until, perhaps, it is so far removed from this that a line prolonged downwards falls beyond the feet; the man then falls, unless, by bending his body and bringing the added weight nearer the centre, he keep the line well within the space which his feet cover.

In the distribution of weights, then, the first rule is to keep the weight nearer to the centre; hence the old mode of carrying the soldier's greatcoat, viz., on the back of the knapsack, is a mistake, as it puts on weight at the greatest possible distance from the centre of gravity.

2. The weights must in no case compress the lungs, or in any way interfere with the respiratory movements, or the elimination of carbonic acid, or hinder the transmission of blood through the lungs, or render difficult the action of the heart.

3. No important muscles, vessels, or nerves should be pressed upon. This is self-evident; an example may be taken from the old Regulation pack, the arm-straps of which so pressed on the axillary nerves and veins as to cause numbness, and often swelling of the hands, which has been known to last for twenty-five hours.

4. The weights should be distributed as much as possible over several parts of the body.

If we consider the means made use of by those who carry great weights, we find the following points selected for bearing them :—

1. The top of the head. The cause of this is obvious; the weight is completely in the line of centre of gravity, and in movement is kept balanced over it. Of course, however, very great weights cannot be carried in this way.

2. The tops of the scapulæ, just over the supra-spinous fossa and ridge. At this point the weight is well over the centre of gravity, and it is also diffused over a large surface of the ribs by the pressure on the scapula.

3. The hip bones and sacrum. Here, also, the weight is near the centre of gravity, and is borne by the strong bony arch of the hips, the strongest part of the body.[1]

In addition, great use is always made by those who carry great weights of the system of balance. The packman of England used to carry from 40 to even 60 ℔ easily thirty miles a day by taking the top of the scapula for the fixed point, and having half the weight in front of the chest and half behind. In this way he still brought the weight over the centre of gravity. The same point, and an analogous system of balance, is used by the milkmaid, who can carry more weight for a greater distance than the strongest guardsman equipped with the old military accoutrements and pack.

These points must guide us in arranging the weights carried by the soldier. The weight on the head is, of course, out of the question. We have, then, the scapulæ, the hip, and the principle of balance to take into consideration.

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[1] The girls engaged in some of the works in Cornwall carry immense bags or hampers of sand up steep hills by resting the lower part of the sack on the hip and sacrum, and the upper part on the scapula. It is the same position as that taken by the Turkish porters, who will carry 600 and 800 ℔ some distance; they also sometimes have a band round the forehead fastened to the top of the weight.

In our army the carriage of the kit and ammunition has always been felt to be a difficulty, and many have been the changes in the infantry knapsacks since the close of the Peninsular war. The method of carriage which was formerly in use, though better than some of the older plans, had grave defects, and it has now been superseded by the new equipment.[1]

The new infantry equipment, proposed by a War Office Committee appointed by Lord de Grey in 1864, and of which General Henry Eyre was the president, was devised for the purpose of enabling the infantry soldier to carry his weights with greater comfort (and, therefore, to enable him to march farther), and especially to do away with any chance of injuring his heart and lungs.[2] This committee presented four reports to the War Office.[3]

Considerable difficulty was found in fixing on the best equipment. In addition to all the points already noted, simplicity and durability, and as much freedom from accidental breakage as could be insured, were essential; facility of removal and readjustment for emergencies, adaptation for various conditions of service, and suitableness for military exercises, had all to be considered. After passing in review all the known plans, and experimenting on a large scale, the committee at last recommended a plan which, after an extended trial in many regiments, and being submitted to the opinions of many officers, was finally authorised and issued in place of the old pattern.

The new equipment is essentially based on the yoke valise plan of the late Colonel Sir Thomas Troubridge, C.B., who had been for many years experimenting on this subject;[4] but it is greatly altered in details in order to avoid the use of copper or iron rods. The two great principles are to use the scapulæ and the sacrum in about equal proportion as carriers of the weight, and to place the weights as near to the body as possible, and, as far as could be done, in front as well as behind, so as to avoid the displacement of the centre of gravity. The great advantage of using the sacrum as one of the points of support has been very apparent in the trials of the valise plan. In that way only can the chest be thoroughly relieved; a very great weight can be carried without injury if it is necessary, and apart from that a mechanical advantage of no small moment has been obtained. For the effect of placing the kit and ammunition low down is to free the large muscles of the shoulder and back from the impediment which hinders their action when a knapsack of any kind is carried in its usual place; the bayonet exercise can therefore be much better performed; but, more than this, the soldier engaged in a personal struggle is in far better position than with a knapsack on the upper part of the back; for, in the latter case, the centre of gravity being displaced (raised and carried backwards), the man has already a tendency to fall back which tells seriously against him. In

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[1] In the former editions descriptions were given of the obsolete Regulation equipment, and of various other plans. But it has been thought unnecessary to repeat these.

[2] In the chapter on HOME SERVICE are given the facts about the amount of heart and vessel disease in the army. It used to be very large, and appeared to be attributable, in part at any rate, to exercise under unfavourable conditions. It was not confined to the infantry, but was common to all branches, and the disease of the vessels was even greater in degree in the cavalry and artillery. Professor Maclean, C.B., called the attention of the authorities to this matter in a striking lecture delivered at the Royal United Service Institution, and published in the *Journal of the Institution*, vol. viii., and from which extracts were given in former editions. The army is greatly indebted to Dr Maclean for his clear exposition on this point. The first *Report of the Committee on Knapsacks* contains the evidence to that date.

[3] *Reports of the Committee appointed to inquire into the Effect on Health of the present System of carrying the Accoutrements, Ammunition, and Kit of Infantry Soldiers: First Report*, 1865; *Second Report*, 1867; *Third and Fourth Reports*, 1868.

[4] Sir T. Troubridge's equipment will be found described and figured in the 2nd edition of this work. He had made experiments on this subject for more than fifteen years.

the new equipment, on the contrary, the great weights being all below the centre of gravity, rather tend to keep a man steadier and firmer on his legs than otherwise.

In order to gain these advantages, and also to lessen the weight of the equipment, the framed knapsack was abandoned, and a bag or valise substituted, which is large enough to carry the service kit and some provisions. The total weight of the whole equipment, as intended for active service is 5 lb 8 oz.[1]

In the peace equipment there is a single pouch in front, which can be shifted to one side so as to allow the waist-belt to be opened. The straps running up over the shoulder from the rings are made broad on the scapulæ, they cross on the back like a common pair of braces, and then catching the top of the valise on the other side by a buckle, run under the arm to the ring on the opposite side from which they started. From this ring a strap runs to the bottom of the valise, which is placed resting on the sacrum; by this arrangement the weight of the valise is thrown partly on the shoulder, partly on the sacrum, and is also thrown forward in a line with the centre of gravity. From the ring another strap runs to the waist-belt and supports the ammunition, which thus balances in part the weight behind.

In full service order two pouches are carried in front, each holding 20 rounds; there is also a ball-bag, intended to hold loose cartridges for rapid firing, in which, if there be necessity, 20 or even 30 cartridges can be put. There is provision in the valise for 20 more.

The greatcoat is placed above the valise, and, being soft, gives no obstruction to the action of the muscles of the shoulder.

The canteen can be carried over the greatcoat; but many officers prefer carrying it on the valise, where there are two loops intended for it.

This equipment is very easy, and leaves the chest perfectly free; it is simple both in principle and construction, and affords many facilities for carriage of articles, such as the haversack, the water-bottle, blanket, &c., which prove useful on service. It is of more importance to note here, that it certainly answers all medical requirements; and, as it leaves the man very free and unencumbered in his movements, it does away entirely with the stiff unmilitary appearance produced by the old plan.

There seems only one sanitary point which has been urged against this equipment, and that is, that a good deal of the back is covered, and that perspiration collects under the valise. Whatever equipment be used, there must be retention of perspiration under the covered parts; this is inevitable, and is produced by any knapsack. The valise equipment is no exception to the rule, but it is singular how little perspiration really collects under the valise if the man knows how to manage it. By allowing the top of the valise to fall back half an inch, a space is left between the greater part of the valise and back, which allows evaporation, and the loins are kept cool. On the march also, when the waist-belt is unbuckled, both the valise and greatcoat hang loosely and away from the body, and evaporation goes on.[2]

The principle of the valise equipment will probably always be maintained, although some details may be altered. The "magazine accoutrements,"

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[1] Lord Wolseley gives the weight of the valise (1882 pattern) as 3 lb, and the accoutrements 4 lb.

[2] Reference may be made to the 2nd edition of this work for figures and descriptions of the continental plans, and to the *Reports of the War Office Committee on Knapsacks and Accoutrements*, for fuller details than can be given here. For the present system, see *Valise Equipment for Infantry Regiments, Instructions for Fitting the*, 1878.

invented by Brigade-Surgeon W. S. Oliver, A.M.D., have been under trial some time, and have been very favourably reported upon. They appear to be even easier than the valise equipment, and are less complicated in their fittings; they provide for the carriage of more ammunition, and leave the back freer for transpiration. There is also a light waterproof cape, which can be used as a sheet or portion of a shelter tent.

SECTION VII.

WORK OF THE SOLDIER.

The kind and amount of work in the different arms of the service is so different that it is impossible to bring it under one general description. In the artillery, cleaning horses, guns, carriages, and accoutrements, and gun drill; in the cavalry, cleaning of horses, accoutrements, and drill with the special arm; in the infantry, drill, and barrack and fatigue duties, and the cleaning of arms and accoutrements, are all kinds of work, the amount of which is not easy to estimate.

Much of the work of the artillery and cavalry is highly beneficial to them, and the fine well-developed muscles show that all parts of the body are properly exercised. Some of the work (such as gun drill or sword exercise) is hard, and even violent, and the great amount of aneurysm in both bodies of men, as well as in the infantry, has led to the idea that the exercise is either too severe, or is performed under unfavourable conditions, such as heavy equipments or too tight fitting clothes. Although violent while it lasts, it seems questionable whether the work is so severe as that which many mechanics undergo without injury; it may, however, be more sudden and rapid, and the heart may be brought into more violent action. The conditions under which the work is done are certainly less favourable than in the case of the mechanic, who is never embarrassed by weights or tight clothes.

In the infantry, the amount of aneurysm is slightly below that of the other arms, but not much so. The hard work in the infantry is the running drill when the weights are carried, bayonet exercise, and long marches; but, though severe, it is not so excessive as to lead us to think it would do injury to strong men if all circumstances were favourable.

During war the amount of labour undergone is sometimes excessive, as will be clear from what is said in the next section, and in the rapid campaigns of modern times very young and weakly men are soon exhausted.

A soldier requires to be trained for the ordeal of active service, and this is now done in our army by a series of gymnastic exercises and systematic marches, intended to develop every muscle, to make the artillery or the cavalry man able to vault on his horse, and the foot soldier to run and to escalade, and to march great distances without fatigue.

Gymnastic Exercises.—All military nations have used in their armies a system of athletic exercises. The Greeks commenced such exercises when the increase of cities had given rise to a certain amount of sedentary life. The Romans began to use athletic training in the early days of the Republic, entirely with a view to military efficiency. The exercises were continuous, and were not alternated with periods of complete idleness.

The officers exercised with the men. At a later day, we are told that Marius never missed a single day at the Campus Martius, and Pompey is

said by Sallust to have been able at fifty-eight years of age to run, jump, and carry a load as well as the most robust soldier in his army.

Swimming was especially taught by the Romans, and so essential were the gymnastic exercises deemed that, to express that a man was completely ignorant, it was said "he knew neither how to read nor swim." The gymnastic exercises were the last of the old customs which disappeared before the increasing luxury of the later empire.

In the feudal times the practice of the weapons was the best gymnastic exercise; every peasant in England was obliged to practise with the bow; the noblemen underwent an enormous amount of exercise, both with and without arms, and on foot and horseback.

After the invention of gunpowder, the qualities of strength and agility became of less importance for the soldier, and athletic training was discontinued everywhere. But within the last few years the changing conditions of modern warfare have again demanded from the soldier a degree of endurance and of rapidity of movement which the wars of the eighteenth century did not require. And the population generally of this conntry have of late years become alive to the necessity of compensating, by some artificial system of mnscular exercise, the sedentary life which so many lead.

In our own time the first regular gymnasinm appears to have been established at Schwefental, in Saxony, by Saltzmann, with a view of giving health to the body, strengthening certain muscles, and remedying deformities. About sixty years ago Ling also commenced in Sweden the system of movements which have made his name so celebrated. Switzerland, Spain, and France followed, and of late years in Germany many gymnastic societies (Tnrner-Verein) have been founded in almost all the great cities, and the literature of gymnasticism is now a large one. In our own country the outdoor and vigorons life led by the richer classes and by many working men rendered this movement less necessary, but of late years societies have been formed, gymnasia established, and athletic sports encouraged in many places.

Among armies, the Swedish and Prussian were the first to attempt the physical training of their soldiers. France followed in 1845, and ever since a complete system of gymnastic instruction has been carried on in the French army, and a military gymnastic school exists at Vincennes, where instructors for the army are tanght.

In the English army this matter attracted less attention until after the Crimean war, when the establishment of gymnasia as a means of training and recreation were among some of the many reforms projected by Lord Herbert. In 1859 General Hamilton and Sir G. Logan, lately Director-General of the Army Medical Department, were sent over to inspect the systems in use on the Continent, and presented a very interesting Report, which was subsequently published. A grant of money was immediately taken for a gymnasium at Aldershot, and this has now been in operation for many years, nnder the direction originally of Colonel Hammersley, with most satisfactory results. Gymnasia are now ordered to be built at all the large stations, and a complete code of instructions, drawn up by Mr Maclaren, of Oxford, is published by authority.[1]

The instructions have two great objects—1*st*, to assist the physical development of the recruit; 2*nd*, to strengthen and render supple the

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[1] *Gymnastic Exercises, &c.*, 1877. Mr Maclaren has also published two other works of great utility; a *System of Training and Physical Education*. This last work should be in the hands of every one.

frame of the trained soldier. Every recruit is now ordered to have three months' gymnastic training during (or, if judged expedient by a medical officer, in lieu of part of) his ordinary drill. Two months are given before he commences rifle practice, and one month afterwards. This training is superintended by a medical officer, who will be responsible that it is done properly, and who will have the power to continue the exercises beyond the prescribed time if he deems it necessary. The exercise for the recruit is to last only one hour a day, and in addition he will have from two to three hours of ordinary drill.

The trained infantry soldier is ordered to go through a gymnastic course of three months' duration every year, one hour being given every other day. The cavalry soldier is to be taught fencing and sword exercise in lieu of gymnastics.

The *Code of Instructions* drawn up by Mr Maclaren consists of two parts, elementary and advanced exercises. The exercises have been arranged with very great care, and present a progressive course of the most useful kind. The early exercise commences with walking and running; leaping, with and without the pole, follows; and then the exercises with apparatus commence, the order being the horizontal beam, the vaulting bar, and the vaulting horse. All these are called exercises of progression. The elementary exercises follow, viz., with the parallel bars, the pair of rings, the row of rings, the elastic ladder, the horizontal bar, the bridge ladder, and the ladder plank. Then follow the advanced exercises of climbing on the slanting and vertical pole, the slanting and vertical rope, and the knotted rope.

Finally, the most advanced exercises consist of escalading, first against a wall, and then against a prepared building.

In the French army swimming and singing are also taught. Both are very useful; the singing is encouraged, not as a matter of amusement (though it is very useful in this way), but as a means of improving the lungs.

Swimming should be considered an essential part of the soldier's education, and it is probable that it will be systematically taught in the English army.

Robert Jackson very strongly recommended that dancing should be taught and encouraged. There is sound sense in this; a spirited dance brings into play many muscles, and in a well-aired room is as good an exercise as can be taken. It would also be an amusement for the men.

Duties of the Officer in the Gymnasium.

The *Medical Regulations* order the inspecting medical officer and surgeon to visit, and advise on the kind and amount of gymnastic exercises. The *Queen's Regulations* (section 10, para. 8) order a strict medical examination of each man before the instruction is commenced. During the course further inspections are to be made—of the recruits once a fortnight, of trained soldiers monthly. The measurements of the recruit are also to be taken under the direction of the medical officer. The following points should be attended in regard to—

1. *Recruits.*—The recruit is inspected from time to time, to see if the system agrees with him.

(*a*) *Weight.*—The weight of the body should be ascertained at the beginning and end of the course, and during it, if the recruit in any way complains. With sufficient food recruits almost always gain in weight, therefore any loss of weight should at once call for strict inquiry. It may be the recruit is being overdone, and more rest may be necessary. But in order to avoid the

greatest error, the weights must be carefully taken; if they are taken at all times of the day, without regard to food, exercise, &c., accuracy is impossible; there may be 2 lb or 3 lb variation. The physiological practice during experiments is to take the weight the first thing in the morning before breakfast, and after emptying the bladder. If it cannot be done at this time, scarcely any reliance can be placed on the result. Food alone may raise the weight 2 lb or 3 lb, and we cannot be sure that the same quantity of food is taken daily. The clothes, also, must be remembered; men should be weighed naked if possible, if not, in their trousers only, and always in the same dress.

(*b*) *Height.*—This is usually taken in the erect position. Sir William Aitken[1] recommends it to be taken when the body is stretched on a horizontal plane. A series of experiments on both plans would be very desirable.

(*c*) *Girth of Chest.*—The chest is measured to ascertain its absolute size and its amount of expansion.

It is best measured when the man stands at attention, with the arms hanging; and the tape should pass round the nipple line. The double tape (the junction being placed on the spine) is a great improvement over the single tape, as it measures the sides separately, and with practice can be done as quickly.

The chest should be measured in the fullest expiration and fullest inspiration. If the chest is measured with the arms extended, or over the head, the scapulæ may throw out the tape from the side of the chest.

(*d*) *The Inspiratory Power*, as expressed by the spirometer, may also be tested.

(*e*) *Growth of Muscles.*—This is known by feeling the muscles when relaxed and in action, and by measurements. The measurement of the upper arm should be taken either when the arm is bent over the most prominent part of the biceps, or over the thickest part when the arm is extended.

(*f*) *General Condition of Health.*—Digestion, sleep, complexion, &c. The recruit should also be inspected during the time of exercise, to watch the effect on his heart, lungs, and muscles. In commencing training the great point is to educate, so to speak, the heart and lungs to perform suddenly, without injury, a great amount of work. To do this there is nothing better than practice in running and jumping. It is astonishing what effect this soon has. If possible, the increase in the number of respirations after running 200 or 300 yards should be noted on the first day, as this gives a standard by which to judge of the subsequent improvement. But as it would be impossible and a waste of time to do this with all the men, directly the run is ended the men should range in line, and the medical officer should pass rapidly down and pick out the men whose respiration is most hurried. In all the exercises the least difficulty of respiration should cause the exercise to be suspended for four or five minutes.[2] The heart should be watched: the characters indicating the necessity for rest or easier work are excessive rapidity (130–160), smallness, inequality, and irregularity.

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[1] *On the Growth of the Recruit*, 2nd edit., 1887.

[2] In the training of horses the points always attended to are—the very gradual increase of the exercise; gentle walking is persevered in for a long time, then slow gallops; then, as the horse gains wind and strength, quicker gallops; but the horse is never distressed, and a boy would be dismissed from a stable if it were known that the horse he was riding showed, by sighing, or in any other way, that the speed was too great for him.

Soreness of muscles after the exercise, or great weariness, should be inquired into. It would be well every now and then to try the inguinal and femoral rings during exertion and coughing.

One very important part in gymnastic training depends on the instructor. A good instructor varies the work constantly, and never urges a man to undue or repeated exertion. If the particular exercise cannot be done by any man it should be left for the time. Anything like urging or jeering by the rest of the men should be strictly discountenanced. The instructor should pass rapidly from exercise to exercise, so that a great variety of muscles may be brought into play for a short time each, and as the men work in classes, and all cannot be acting at once, there is necessarily a good deal of rest.

The grand rule for an instructor is, then, change of work and sufficient rest.

In the case of a recruit who has not been used to much physical exertion, the greatest care must be taken to give plenty of rest during exercises. There may even seem to be an undue proportion of rest for the first fortnight, but it is really not lost time. The medical officer is only directed to visit the gymnasium once a fortnight, but during the first fortnight of the training of a batch of recruits he should visit it every day.

With proper care men are very seldom injured in gymnasia. Dr Parkes was informed at Vincennes that, though they did not take men unless they were certified as fit by a medical officer, they occasionally got men with "delicate chests," though not absolutely diseased. These men always improved marvellously during the six months they remained at Vincennes. In fact, a regulated course of gymnastics is well known to be an important remedial measure in threatened phthisis. Hernia is never caused at Vincennes. Nor does it appear that any age is too great to be benefited by gymnastics, though in old men the condition of the heart and vessels (as to rigidity) should be looked to.

Trained Soldiers.—There is less occasion for care with these men; they should, however, be examined from time to time, and any great hurry of respiration noted. The man should be called out from the class, his heart examined, and some relaxation advised if necessary.

Drills and Marches.

In drill, and during marches, the movements of the soldiers are to a certain extent constrained. In the attitude of "attention" the heels are close together, the toes turned out at an angle of 60°, the arms hang close by the sides, the thumbs close to the forefingers, and on a line with the seam of the trousers. The position is not a secure one, as the basis of support is small, and in the manual and platoon exercise the constant shifting of the weight changes the centre of gravity every moment, so that constant muscular action is necessary to maintain the equilibrium. Men are therefore seldom kept long under attention, but are told to "stand at ease" and "stand easy," in which cases, and especially in the latter, the feet are farther apart and the muscles are less constrained.

In marching the attitude is still stiff—it is the position of attention, as it were, put into motion. The slight lateral movement which the easy walker makes when he brings the centre of gravity alternately over each foot, and the slight rotatory motion which the trunk makes on the hip-joint, is restrained as far as it can be, though it cannot be altogether avoided, as is proved by observing the light swaying motion of a line of even very steady men marching at quick time. Marching is certainly much more fatiguing

than free walking; and in the French army, and by many commanding officers in our own, the men are allowed to walk easily and disconnectedly, except when closed up for any special purpose. This may not look so striking to the eye of a novice, but to the real soldier, whose object is at the end of a long march to have his men so fresh that, if necessary, they could go at once into action, such easy marching is seen to be really more soldier-like than the constrained attitudes which lead so much sooner to the loss of the soldier's strength and activity.

In walking, the heel touches the ground first, and then rapidly the rest of the foot, and the great toe leaves the ground last. The soldier, in some countries, is taught to place the foot almost flat on the ground, but this is a mistake, as the body loses in part the advantage of the buffer-like mechanism of the heel. The toes are turned out at an angle of about 30° to 45°, and at each step the leg advances forward and a little outward; the centre of gravity, which is between the navel and the pubis, about in a line with the promontory of the sacrum (Weber), is constantly shifting. It has been supposed that it would be of advantage to keep the foot quite straight, or to turn the toes a little in, and to let the feet advance almost in a line with each other. But the advantage of keeping the feet apart and the toes turned out is that, first, the feet can advance in a straight line, which is obviously the action of the great *vasti* muscles in front of the thigh; and, second, when the body is brought over the foot, the turned-out toes give a much broader base of support than when the foot is straight. The spring from the great toe may perhaps be a little greater when the foot is straight (although this is doubtful, and there seems no reason why the gastrocnemii and solei should contract better in this position), but there is a loss of spring from the other toes. Besides this, it has been shown by Weber that when the leg is at its greatest length, *i.e.*, when it has just urged the body forward, and is lifted from the ground, it falls forward like a pendulum from its own weight, not from muscular action, and this advance is from within and behind to without and before, so that this action alone carries the leg outwards.

The foot should be raised from the ground only so far as is necessary to clear obstacles. Formerly, in the Russian Imperial Guard, the men were taught to march with a peculiar high step, the knee being lifted almost to a level with the acetabulum. The effect was striking, but the waste of power was so great that long marches were impossible, and this kind of marching is now given up. The foot should never be advanced beyond the place where it is to be put down: to do so is a waste of labour.

In the English army the order is as follows:—

Length and Number of Steps in Marching.

Kind of Step.	Length.	No. per Minute.	Ground Traversed per Minute.	Ground Traversed per Hour without Halts.
	Inches.		Feet.	Miles.
Slow time,	30	75	187½	2·1
Quick time,	30	116	290	3·3
Stepping out,	33	110	303½	3·4
Double,	33	165	453¾	5·157
Stepping short,	21	...	...	...
Side step,	12	...	...	...
Or when Forming four deep,	24	...	...	...
Stepping back,	30	...	...	...

The "double" is never continued very long; it is stopped at the option of the commanding officer. In the French army it is ordered not to be continued longer than twenty minutes. At the double (if without arms), the forearms are held horizontally, the elbows close to the side; if the rifle is carried, one arm is so held. There is an advantage in this attitude, as the arms are brought into the position of least resistance; more fixed points are given for the muscles of respiration, and the movement of the arms and shoulders facilitates the rapid shifting of the centre of gravity.

Quick time is always used in drills and marching. The ground got over per hour is generally reduced by halts to 2·8 miles.

Running drill has been introduced of late years; it is not carried beyond 1000 yards, and the men are gradually brought up to this amount. The pace is not to exceed 6 miles an hour. Weakly men (if considered unfit by the medical officers) are to be excused.[1]

In the French army the length of step is rather different.

French Steps in English Measures (*Morache*, 1886).

	Length of Step in inches.	Steps per Minute.	Ground Traversed per Minute in Feet.	Ground Traversed per Hour in Miles.
Pas accéléré, .	29·5	120 to 135	295 to 332	3·35 to 3·80
Pas maximum (gymnastique),	31·5	170	446	5·10

The French step is therefore nearly the same as the English under the new regulations. The Prussian and the Bavarian step is $31\frac{1}{2}$ inches long, and 112 steps are taken per minute.

The exact length of the step, and the number per minute, are very important questions. The object of the soldier is to get the step as long, and the number per minute as great, as possible, without undue fatigue, so as to get over the greatest amount of ground.

The quickest movement of the leg forward in walking has been shown by Weber to correspond very closely with half a pendulum vibration of the leg, and to occupy on an average, 0·357 seconds; this would give 168 steps per minute, supposing the one foot left the ground when the other touched it. This is much quicker than the army walking step (the double is a run), and no doubt much quicker than could long be borne, since, with a step of only 30 inches, it would give nearly five miles per hour; but it may be a question whether, with men in good condition, the pace might not be increased to 130 per minute. Practical trials, however, with soldiers carrying arms and accoutrements, can alone decide this point.

The length of the step of an average man has been fixed by the Brothers Weber at about 28 inches. In individual cases it depends entirely on the length of the legs. · Robert Jackson considered 30 inches as too long a step for the average soldier, and suggested 27 inches. It is of great importance not to lessen the length too much, and it would be very desirable to have some well-conducted experiments on this point. The steps must be shorter if weights are carried than without them; a little consideration shows how this is: When a man walks, he lifts his whole body and propels it forward, and in doing so the point of centre of gravity describes a circular motion, in the form of an arc about the foot. The less the body is raised, or, in other words, the shorter the versed sine of the arc, the less of course the labour.

[1] *Queen's Reg.*, 1885, section 10, para. 25*a*.

In long steps the arc, and of course the versed sine, or height to which the body is raised, are greater; in short steps, less.[1] It is probable, with the weight the soldier carries (60 lb), the step of 30 inches is quite long enough, perhaps even too long; and it would be desirable to know if, after a march of six or eight miles, the steps do not get shorter.

In the French army the march is commenced at 120 steps per minute; then accelerated to 125 or even 135 steps; during the last half-hour 120 steps are returned to.[2] But the soldiers themselves often set the step; the grenadiers and the voltigeurs alternately leading. Four kilometres ($=2\frac{1}{2}$ miles) per hour is considered a good general average (Morache).

The soldier, in this country, when he marches in time of peace in heavy order, carries his pack, kit, haversack, water-bottle, greatcoat, rifle, and ammunition (probably twenty rounds). In India he does not carry his pack or greatcoat.

There is a very general impression that the best marchers are men of middle size, and that very tall men do not march so well.

Length of the March.—In "marching out" in time of peace, which is done once or twice a week in the winter, the distance is 8 or 10 miles.[3] In marching on the route or in war, the distance is from 10 or 12 miles to occasionally 18 or 20, but that is a long march. A forced march is any distance—25 to 30, and occasionally even 40 miles being got over in twenty-four hours. In the French army the length of march is from 20 to 25 kilometres ($12\frac{1}{2}$ to 15 miles). In the Prussian army the usual march is 14 miles (English); if the march is continuous, there is a halt every fourth day. Anything beyond this is rarely achieved, except occasionally by small bodies of men.

Conditions rendering Marches Slower.—The larger the body of men the slower the march; 14 miles will be done in six or seven hours by two or three regiments, but not under eight or nine hours by 8000 or 10,000 men. A large army will not go over 14 miles under ten hours usually. A single regiment can do 20 miles in eight hours, but a large army will take twelve or fourteen, including halts. Head winds greatly delay marches; a very strong wind acting on a body of men will cause a difference of 20 to 25 per cent., or only 4 miles will be got over instead of 5.

Snow and rain, without head wind, delay about 10 to 15 per cent., or $4\frac{1}{2}$ miles are done instead of 5.

Of course bad or slippery roads, deep sands, heavy snows, jungle and brushwood, are often acting against the soldier, and in hilly and jungly countries only 5 or 6 miles may be got over in a day.

Conditions adding to the Fatigue of Marching.—Heat—dust—thirst—constant halts from obstructions—want of food—bad weather, especially head winds with rain. In order to avoid heat and dust, it is desirable, when it can be done, to separate the cavalry and artillery from the infantry; to let the latter march in open order, and with as large a front as possible.

Instances of Marches during War.—It is most important for a soldier to know what has been done and what can be done with a large body of foot soldiers, and it is scarcely less interesting to the physiologist. In comparing the marches of infantry, it must always be remembered how great an effect increasing the number of men has in lessening the rapidity and length of a

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[1] The Brothers Weber, however, have shown that the angle at which the body is bent, and, consequently, the coefficient of resistance, are not affected by the length of step, provided the velocity remains the same.

[2] Morache, *op. cit.*, p. 761.

[3] *Queen's Regulations*, 1885, section 16, para. 6. See also *Field Exercise* (1877).

march, and in increasing the fatigue. No large army has ever made the marches small bodies of troops have done.

At times the fatigue undergone by trained men has been something almost incredible. Wolfe mentions in one of his letters that in 1743, just before the battle of Dettingen, his regiment marched from Frankfort "two days and two nights with only nine or ten hours' halt." This would be a march of thirty-eight hours out of forty-eight. He gives the distance at about 40 miles, but it was probably more. The 43rd, 52nd, and 95th regiments of foot, forming the Light Division under Crawfurd, made a forced march in July 1809, in Spain, in order to reinforce Sir Arthur Wellesley at the battle of Talavera. About fifty weakly men were left behind, and the brigade then marched 62 miles in twenty-six hours, carrying arms, ammunition, and pack —in all, a weight of between 50 ℔ and 60 ℔.[1] There were only seventeen stragglers. The men had been well trained in marching during the previous month.

One of these regiments—the 52nd—made in India, in 1857, a march nearly as extraordinary. In the height of the Mutiny intelligence reached them of the locality of the rebels from Sealkote. The 52nd, and some artillery, started at night on the 10th of July 1857 from Umritzur, and reached Goodasepore, 42 miles off, in twenty hours, some part of the march being in the sun. On the following morning they marched 10 miles, and engaged the mutineers. They were for the first time clad in the comfortable grey or dust-coloured native khaki cloth.

A march of a small party of French was narrated by an officer of the party, who was afterwards wounded at Sedan, to Dr Frank. A company of a regiment of chasseurs of Macmahon's army, after being on grand guard, without shelter or fire, during the rainy night of the 5th–6th August 1870, started at three in the morning to rejoin its regiment in retreat on Niederbronn, after the battle of Weissenburg. It arrived at this village at 3.30 in the afternoon, and started again for Phalsbourg at 6 o'clock. The road was across the hills, and along forest tracts, which were very difficult for troops. It arrived at Phalsbourg at 8.30 o'clock in the evening of the next day. The men had, therefore, marched part of the night of the 5th–6th August, the day of the 6th, the night of the 6th–7th, and day of the 7th till 8.30 P.M. The halts were eight minutes every hour from 3.30 to 6, one hour in the night of the 6th–7th, and 2½ hours on the 7th. Altogether, including the halts, the march lasted 41½ hours, and the men must have been actually on their feet about thirty hours, in addition to the guard duty on the night before the march.

An officer of a Saxon fusilier regiment gave the following statement of a forced march in one of the actions at Metz in 1870. The regiment was alarmed at midnight and marched at 1 A.M., and continued marching with halts until 7 P.M.; they bivouacked for the night, marched at 7 the next morning, came into action at 1.30, and in the evening found themselves 15 kilometres beyond the field of battle. The total distance was 53½ miles in about forty-two hours, with probably fifteen hours' halt.

Roth mentions that the 18th division of the Saxon army in the various

[1] Napier's *War in the Peninsula*, 3rd edit., vol. ii. p. 400; Moorsom's *Record of the 52nd Regiment*, p. 115. Both authors state that the men carried between 50 ℔ and 60 ℔ on this extraordinary march, but there seems a little doubt of this. During the Peninsular war the men carried bags, weighing about 2 ℔, and not framed packs, and their kits were very scanty. Lord Clyde, in talking of this march to Surgeon-General Sir T. Longmore, told him the men only carried a shirt and a spare pair of either boots or soles. He saw the men march in. In all probability also they would not carry their full ammunition.

manœuvres about Orleans marched, on the 16th and 17th December 1870, 54 English miles.

Von der Tann's Bavarian army, in retreat on Orleans, marched 42 miles in twenty-six hours.

These were all forced marches for the purpose of coming into action or retiring after discomfiture. Apart from the Peninsular Light Division march, they show that in two days and one night a small body of men may cover 54 English miles, and that is probably near the limit of endurance. The Light Division march is so excessive (62 miles in twenty-six hours, or 2·38 miles every hour, without reckoning halts) that it may be doubted if the distance was properly reckoned.[1]

When a large army moves it has never accomplished such distances.

In 1806 the French army marched on one occasion 49 kilometres, or 30½ miles. On the 15th June 1815, Napoleon made a forced march to surprise the Prussians and English, but only accomplished 30 kilometres, or 18⅗ miles.

In Sherman's celebrated march across the Southern States the daily distance was about 14 miles. When the Prussians advanced on Vienna, after the battle of Königgrätz in 1866, they accomplished almost the same, and had also outpost duty every other night.

The Russians marched in the expedition to Khiva, in 1873, 468·7 miles (English) in 89 days, but as actual marching was done only on 44 days, the average daily march was (468·7 ÷ 44) 10·65 miles; the longest march was 26½ miles.[2]

Macmahon's army, in its march to relieve Bazaine at Metz, could only accomplish about 10 miles daily, while the Crown Prince of Prussia in pursuit was far more rapid.

After Sedan, the Prussian and Saxon troops pushed on to Paris by forced marches, and accomplished on an average 35 kilometres, or 21⅗ miles, daily, and they marched on some days 42 to 45 kilometres (26 to 28 miles); they started at 5 or 6, and were on their ground from 4 to 8 o'clock, the average pace being 5 kilometres (3·1 miles) per hour.

In the Indian Mutiny several regiments marched 30 miles a day for several days.

When marches are continued day after day, an average of about 20 miles may be expected from men for two or three weeks, after which, probably, the amount would lessen.

It is difficult to estimate the labour of such marches, as besides the actual

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[1] Sir William Cope, who was one of the officers of the 95th, says (in his *History of the Rifle Brigade, formerly the 95th*) that the distance was only 40 miles.

[2] In 1709, on the 3rd Sept., in order to secure the passage of the Haine, the Prince of Hesse-Cassel made a march of 49 English miles in 56 successive hours, with 4000 foot and 60 squadrons (Coxe's *Life of Marlborough*, v. 10–21).

Alison (*History of Marlborough*, vol. ii. p. 27) says that "this rapidity of advance for such a distance had never been previously surpassed, though it has been outdone in later times." He refers in a footnote to Mackenzie's march to join Wellington at Talavera, which he gives as 62 English miles in 26 hours; also the Russian foot guards advancing to Paris in 1814, after the combat at Fére-Champenoise, marched 48 miles in 26 hours.

In the *Times* of 1873 a writer gives the following statement; he quotes from a dispatch published in the *London Gazette* of 1859:—"During the day the troops from Khulkhulla marched 35 miles, and those from the camp 48 miles, and much of this under a more than usually hot sun." He also says that at the end of 1858 General Whitlock marched 86 miles in 37 hours to relieve Kirwee.

In April 1859 Colonel De Salis (*London Gazette*, 1859) reported a march of not less than 40 miles. Captain Rennie's force also marched 40 miles in 24 hours. In the same number of the *Times* Captain Carleton states that Daly's Guide Corps marched from near Peshawur to Delhi, 580 miles, in 22 days. Sir Hope Grant says 750 miles in 28 days. He also says that the 1st Bengal Fusiliers (European) marched 68 miles in 38 hours.

march there is often work in fetching water, cooking, pitching tents, sentry, outpost, and picket duty, &c. As 20 miles a day with 60 ℔ weight is equivalent to lifting 495 tons one foot, and there is always additional work to be done, it is clear that the labour is excessive, and must be prepared for, and that during the time the men must be well fed.

In marching long distances, the extent of the marches, the halting grounds, &c., are fixed by the Quartermaster-General's department.

Occasionally the march has been divided, one part being done in the early morning, and the remainder late in the afternoon. It is, however, better to make the march continuous, and, if necessary, to lengthen the mid-day halt.

Order of March.—Whenever possible, it seems desirable to march in open order. Inspector-General J. R. Taylor has given evidence to show that a close order of ranks is a cause of unhealthiness in marching, similar to that of overcrowding in barracks; and the Medical Board of Bengal, in accordance with this opinion, recommended that military movements in close order should be as little practised as possible. There should also be as much interval as can be allowed between bodies of troops.

Effects of Marches.—Under ordinary conditions, both in cold and hot countries, men are healthy on the march.

But marches are sometimes hurtful—

1*st.* When a single long and heavy march is undertaken when the men are overloaded, without food, and perhaps without water. The men fall out, and the road becomes strewed with stragglers. Sometimes the loss of life has been great.

The prevention of these catastrophes is easy. Place the soldier as much as possible in the position of the professional pedestrian; let his clothes and accoutrements be adapted to his work; supply him with water and proper food, and exclude spirits; if unusual or rapid exertion is demanded, the weights must be still more lightened.

When a soldier falls out on the march he will be found partially fainting, with cold moist extremities, a profuse sweat everywhere; the pulse is very quick and weak—often irregular; the respiration often sighing. The weights should be removed, clothes loosened, the man laid on the ground, cold water dashed on the face, and water given to drink in small quantities. If the syncope is very alarming, brandy must be used as the only way of keeping the heart acting, but a large quantity is dangerous. If it can be obtained, weak hot brandy and water is the best under these circumstances. When he has recovered, the man must not march—he should be carried in a wagon, and in a few minutes have something to eat, but not much at a time. Concentrated beef-tea mixed with wine is a powerful restorative, just as it is to wounded men on the field.

2*nd.* When the marches which singly are not too long are prolonged over many days or weeks without due rest.

With proper halts men will march easily from 500 to 1000 miles, or even farther, or from 12 to 16 miles per diem, and be all the better for it; but after the second or third week there must be one halt in the week besides Sunday. If not, the work begins to tell on the men; they get out of condition, the muscles get soft, appetite declines, and there may be even a little anæmia. The same effects are produced with a much less quantity of work if the food is insufficient. Bad food and insufficient rest are then the great causes of this condition of body.

In such a state of body malarious fevers are intensified, and in India attacks of cholera are more frequent. It has been supposed that the body is

overladen with the products of metamorphosis, which cannot be oxidised fast enough to be removed.

Directly the least trace of loss of condition begins to be perceived in the more weakly men (who are the tests in this case), the surgeon should advise the additional halt, if military exigencies permit. On the halt day the men should wash themselves and their clothes, and parade, but should not drill.

3rd. When special circumstances produce diseases.

Exposure to wet and cold in temperate climates is the great foe of the soldier. As long as he is marching, no great harm results; and if at night he can have dry and warm lodgings he can bear, when seasoned, great exposure. But if he is exposed at night as well as day, and in war he often is so, and never gets dry, the hardiest men will suffer. Affections arising from cold, such as catarrhs, rheumatism, pulmonary inflammation, and dysentery are caused.

These are incidental to the soldier's life, and can never be altogether avoided. But one great boon can be given to him: a waterproof sheet, which can cover him both day and night, has been found the greatest comfort by those who have tried it.

The soldier may have to march through malarious regions. The march should then be at mid-day in cold regions, in the afternoon in hot. The early morning marches of the tropics should be given up for the time; the deadliest time for the malaria is at and soon after sunrise. If a specially deadly narrow district has to be got through, such as a Terai, at the foot of hills, a single long march should be ordered; a thoroughly good meal, with wine, should be taken before starting, and, if it can be done, a dose of quinine. If the troops must halt a night in such a district, every man should take five grains of quinine. Tents should be pitched in accordance with the rules laid down in the chapter on CAMPS, and the men should not leave them till the sun is well up in the heavens.

Yellow fever or cholera may break out. The rules in both cases are the same. At once leave the line of march; take a short march at right angles to the wind; separate the sick men, and place the hospital tent to leeward; let every evacuation and vomited matter be at once buried and covered with earth, or burnt, if possible, and employ natives (if in India) to do this constantly, with a sergeant to superintend. Let every duty-man who goes twice to the rear in six hours report himself, and, if the disease be cholera, distribute pills of acetate of lead and opium to all the non-commissioned officers. Directly a man who becomes choleraic has used a latrine, either abandon it, or cover it with earth and lime if it can be procured. If there is carbolic acid or chloride of zinc, or lime or sulphate of iron or zinc at hand, add some to every stool or vomit.

In two days, whether the cholera has stopped or not, move two miles; take care in the old camp to cover or burn everything, so that it may not prove a focus of disease for others. The drinking water should be constantly looked to. A regiment should never follow one which carries cholera; it should avoid towns where cholera prevails; if it itself carries cholera, the men should not be allowed to enter towns. Many instances are known in India where cholera was in this way introduced into a town.

The men may suffer from insolation. This will generally be under three conditions. Excessive solar heat in men unaccustomed to it and wrongly dressed, as in the case of the 98th in the first China war, when the men, having first landed from a six months' voyage, and being buttoned up and wearing stocks, fell in numbers during the first short march. A friend who followed with the rearguard informed Dr Parkes that the men fell on their

faces as if struck by lightning; on running up and turning them over, he found many of them already dead. They had, no doubt, struggled on to the last moment. This seems to be intense asphyxia, with sudden failure of the heart-action, and is the "cardiac variety" of Morehead.

A dress to allow perfectly free respiration (freedom from pressure on chest and neck), and protection of the head and spine from the sun, will generally prevent this form. The head-dress may be wetted from time to time; a piece of wet paper in the crown of the cap is useful. When the attack has occurred, cold affusion, artificial respiration, ammonia, and hot brandy and water to act on the heart, seem the best measures. Bleeding is hurtful; perhaps fatal. Cold affusion must not be pushed to excess.

In a second form the men are exposed to continued heat,[1] both in the sun and out of it, day and night, and the atmosphere is still, and perhaps moist, so that evaporation is lessened, or the air is vitiated. If much exertion is taken, the freest perspiration is then necessary to keep down the heat of the body; if anything checks this, and the skin gets dry, a certain amount of pyrexia occurs: the pulse rises; the head aches; the eyes get congested; there is a frequent desire to micturate (Longmore), and gradual or sudden coma, with perhaps convulsions and stertor, comes on, even sometimes when a man is lying quiet in his tent. The causes of the interruption to perspiration are not known; it may be that the skin is acted upon in some way by the heat, and, from being over-stimulated, at last becomes inactive.

In this form cold affusion, ice to the head, and ice taken by the mouth are the best remedies; perhaps even ice water by the rectum might be tried. Stimulants are hurtful. The exact pathology of this form of insolation is uncertain. It is the cerebro-spinal variety of Morehead.

In a third form a man is exposed to a hot land-wind; perhaps, as many have been, from lying drunk without cover. When brought in there is generally complete coma, with dilated pupils and a very darkly flushed face. After death the most striking point is the enormous congestion of the lungs, which is also marked, though less so, in the other varieties. Dr Parkes stated that he had never seen anything like the enormous congestion he had observed in two or three cases of this kind.

As prevention of all forms, the following points should be attended to:—suitable clothing; plenty of cold drinking water (Crawford); ventilation; production in buildings of currents of air; bathing; avoidance of spirits; lessening of exertion demanded from the men.

Duty of Medical Officers during Marches.

General Duties on Marches in India or the Colonies.—Before commencing the march, order all men with sore feet to report themselves. See that all the men have their proper kits, neither more nor less. Every man should be provided with a water-bottle to hold not less than a pint. Inspect halting-grounds, if possible; see that they are perfectly clean, and that everything is ready for the men. In India, on some of the trunk roads there are regular halting-grounds set apart. The conservancy of these should be very carefully looked to, else they become nothing but foci for disseminating disease. If there are no such places, halting-grounds are selected. It should be a rule never to occupy an encamping ground previously used by another corps if it can be avoided; this applies to all cases. Select a position to windward of such an old camp, and keep as far as possible from it. The encampments

[1] The heat of sandy plains is the worst, probably from the great absorption of heat and the continued radiation. The heat of the sun, *per se*, is not so bad; on board ship sun-stroke is uncommon.

of the transport department, elephants, camels, bullock carts, &c., must be looked to,—they often are very dirty: keep them to leeward of the camp, not too near, and see especially that there is no chance of their contaminating streams supplying drinking water. If the encampment is on the banks of the stream, the proper place for the native camp and bazaar will always be lower down the stream. The junior medical officer, if he can be spared, should be sent forward for this purpose with a combatant officer. Advise on length of marches, halts, &c., and draw up a set of plain rules to be promulgated by the commanding officer, directing the men how to manage on the march if exposed to great heat or cold, or to long-continued exertion, how to purify water, clean their clothes, &c. If the march is to last some time, and if halts are made for two or three days at a time, write a set of instructions for ventilating and cleaning tents, regulation of latrines, &c.

Special Duties for the March itself.—Inspect the breakfast or morning refreshment; see that the men get their coffee, &c. On no account allow a morning dram, either in malarious regions or elsewhere. Inspect the water-casks, and see them properly placed, so that the men may be supplied; inspect some of the men, to see that the water-bottles are full. March in rear of the regiment so as to pick up all the men that fall out, and order men who cannot march to be carried in wagons, dhoolies, &c., or to be relieved of their packs, &c. If there are two medical officers, the senior should be in rear; if a regiment marches in divisions, the senior is ordered to be with the last. When men are ordered either to be carried or to have their packs carried, tickets should be given specifying the length of time they are to be carried. These tickets should be prepared before the march, so that nothing has to be done but to fill in the man's name, and the length he is to be carried.

Special orders should be given that, at the halt, or at the end of the day's march, the heated men should not uncover themselves. They should take off their pack and belts, but keep on the clothes, and, if very hot, should put on their greatcoats. The reason of this (viz., the great danger of chill *after* exertion) should be explained to them. In an hour after the end of the march the men should change their underclothing and hang the wet things up to dry; when dry they should be shaken well, and put by for the following day. Some officers, however, prefer that their men should at once change their clothes and put on dry things. This is certainly more comfortable. But, at any rate, exposure must be prevented.

At the end of the march inspect the footsore men. Footsoreness is generally a great trouble, and frequently arises from faulty boots, undue pressure, chafing, riding of the toes from narrow soles, &c. Rubbing the feet with tallow, or oil or fat of any kind, before marching, is a common remedy. In the late war the Germans found tannin very useful,—they used an ointment of one part of tannin to twenty parts of zinc ointment. A good plan is to dip the feet in very hot water, before starting, for a minute or two; wipe them quite dry, then rub them with soap (soft soap is the best) till there is a lather; then put on the stocking. At the end of the day, if the feet are sore, they should be wiped with a wet cloth, and rubbed with tallow and spirits mixed in the palm of the hand (Galton). Pedestrians frequently use hot salt and water at night, and add a little alum. The German soldiers use *Pulvis salicylicus cum Talco* (German Pharmacopœia); this is salicylic acid 3 parts, wheaten starch 10 parts, talc 87 parts; mix to a fine powder; it is applied daily on the march; in garrison every 2 or 3 days. Sometimes the soreness is owing simply to a bad stocking; this is easily remedied. Stockings should be frequently washed; then greased.

Some of the German troops use no stockings, but rags folded smooth over the feet. The French use no stockings. Very often soreness is owing to neglected corns, bunions, or in-growing nails, and the surgeon must not despise the little surgery necessary to remedy these things; nothing, in fact, can be called little if it conduces to efficiency. As shoes are often to blame for sore feet, it becomes a question whether it might not be well to accustom the soldier to do without shoes.

Frequently men fall out on the march to empty the bowels; the frequency with which men thus lagging behind the column were cut off by Arabs, led the French in Algeria to introduce the slit in the Zouave trousers, which require no unbuckling at the waist, and, take no time for adjustment.

At a long halt, if there is plenty of water, the shoes and stockings should be taken off and the feet well washed; even wiping with a wet towel is very refreshing. The feet should always be washed at the end of the march.

Occasionally men are much annoyed with chafing between the nates or inside of the thighs. Sometimes this is simply owing to the clothes, but sometimes to the actual chafing of the parts. Powders are said to be the best—flour, oxide of zinc, and, above all, it is said, fuller's earth.

If blisters form on the feet, the men should be directed not to open them during the march, but at the end of the time to draw a needle and thread through; the fluid gradually oozes out.

All footsore men should be ordered to report themselves at once.

Sprains are best treated with rags dipped in cold water, or cold spirit and water with nitre, and bound tolerably tight round the part. Rest is often impossible. Hot fomentations, when procurable, will relieve pain.[1]

Marches, especially if hurried, sometimes lead men to neglect their bowels, and some trouble occurs in this way. As a rule, it is desirable to avoid purgative medicines on the line of march, but this cannot always be done; they should, however, be as mild as possible.

Robert Jackson strongly advised the use of vinegar and water as a refreshing beverage, having probably taken this idea from the Romans, who made vinegar one of the necessaries of the soldier. It was probably used by them as an anti-scorbutic; whether it is very refreshing to a fatigued man seems uncertain.

There is only one occasion when spirits should be issued on a march: this is on forced marches, near the end of the time, when the exhaustion is great. A little spirit, in a large quantity of hot water, may then be useful, but it should be used only on great emergency. Warm beer or tea is also good; the warmth seems an important point. Ranald Martin and Parkes tell us that in the most severe work in Burmah, in the hot months of April and May, and in the hot hours of the day, warm tea was the most refreshing beverage. Travellers in India, and in bush travelling in Australia, have said there was nothing so reviving as warm tea. Chevers mentions that the juice of the country onion is useful in lessening thirst during marches in India, and that, in cases of sun-stroke, the natives use the juice of the unripe mangoe mixed with salt.

Music on the march is very invigorating to tired men. Singing should also be encouraged as much as possible.

Marching in India.—Marches take place in the cool season (November to February), and not in the hot or rainy seasons, except on emergency; yet marches have been made in hot weather without harm, when care is taken. They are conducted much in the same way as in cold countries, except that

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[1] The following is a very good lotion for sprains:—sal-ammoniac, 20 grains; vinegar and spirit, an ounce of each.

the very early morning is usually chosen. The men are roused at half-past two or three, and parade half an hour later; the tents are struck, and carried on by the tent-bearers; coffee is served out, and the men march off by half-past three or four, and end at half-past seven. Everything is ready at the halting-ground, tents are pitched, and breakfast is prepared.

These very early marches are strongly advocated by many, and are opposed almost as strongly by some. In the West Indies marching in the sun has always been more common than in the East. Much must depend on the locality, and the prevalence and time of hot land-winds. Both in India and Algeria marches have been made at night; the evidence of the effects of this is discordant. The French have generally found it did not answer; men bear fatigue less well at night; and it is stated that the admissions into hospital have always increased among the French after night marching. Annesley's authority is also against night marching in India. On the other hand, it is stated by some that in India the march through the cool moonlight night has been found both pleasant and healthy.

Afternoon marches (commencing about two hours before sunset) have been tried in India, and often apparently with very good results.

Marching in Canada.—In 1814, during the war with America; in 1837, during the rebellion; and in 1861–62, during the "Trent" excitement, winter marches were made by the troops, in all cases without loss. The following winter clothing was issued at home:—A sealskin cap with ear lappets; a woollen comforter; two woollen jerseys; two pairs of woollen drawers; a chamois leathern vest with arms; two pairs long woollen stockings to draw over the boots; sealskin mits; and a pair of jackboots. In Canada a pair of blankets and mocassins were added,[1] and, at the long halts, weak hot rum and water was served out. A quarter of a pound of meat was added to the ration. A hot meal was given before starting, another at mid-day, and another at night. The troops were extremely healthy. During exposure to cold, spirits must be avoided; hot coffee, tea, ginger tea, or hot weak wine and water are the best; it is a good plan to rub the hands, feet, face, and neck with oil; it appears to lessen the radiation of heat and the cooling effect of winds.

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[1] See Inspector-General Muir's Report, *Army Medical Reports*, vol. iv. p. 378.

CHAPTER III.

THE EFFECTS OF MILITARY SERVICE.

The influence of the various conditions of military life is shown by the records of sickness and mortality, and this must be noted in the various stations.

The recruit having entered the ranks, begins his service at home, and he is kept at his depôt for some time. He does not go on foreign service until he has completed his twentieth year. We should suppose his life would be a healthy one. It is a muscular, and, to a certain extent, an open-air life, yet without great exposure or excessive labour; the food is good (though there might be some improvement), the lodging is now becoming excellent, and the principles of sanitation of dwellings are carefully practised. Although the mode of clothing might be improved as regards pressure, still the material is very good. There is a freedom from the pecuniary anxiety which often presses so hardly on the civil artisan, and in illness the soldier receives more immediate and greater care than is usual in the class from which he comes.

There are some counterbalancing considerations. In a barrack there is great compression of the population, and beyond a doubt the soldier has greatly suffered, and even now suffers, from the foul air of barrack rooms. But this is a danger greatly lessening, owing to the exertions of the Barrack Improvement Commissioners, and, as is proved by the experience of some convict jails, can be altogether avoided.

Among the duties of the soldier is some amount of night-work; it is certain that this is a serious strain, and the Sanitary Commissioners, therefore, inserted in the *Medical Regulations* an order that the number of nights in bed should be carefully reported by medical officers. General Sir Frederick Roberts, G.C.B., has lately called marked attention to the injurious effects of night duty and "sentry-go."[1] Commanding officers should be informed how seriously the guard and sentry duties, conducted as they are in full dress, tell on the men if they are too frequent. One guard-day in five is quite often enough, and four nights in bed should be secured to the men. Exposure during guard and transition of temperature on passing from the hot air of the guard-room to the outside air are also causes of disease. The weights and accoutrements are heavy, but the valise equipment introduced by General Eyre's Committee has removed the evil of the old knapsack.

The habits of the soldier are unfavourable to health; in the infantry, especially, he has much spare time on his hands, and *ennui* presses on him. *Ennui* is, in fact, the great bane of armies, though it is less in our own than in many others. It is said to weigh heavily on the German, the Russian, and even on the French army. Hence, indeed, part of the restlessness, and one of the dangers of large standing armies. The Romans appear to have avoided this danger by making their distant legions stationary, and permitting marriage and settlement—in fact, by converting them into military colonies.

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[1] *Nineteenth Century*, Nov. 1882.

We avoid it in part by our frequent changes of place, and our colonial and Indian service; but not the less, both at home and abroad, do idleness and *ennui*, the parents of all evils, lead the soldier into habits which sap his health. Not merely excessive smoking, drinking, and debauchery, but in the tropics mere laziness and inertia, have to be combated. Much is now being done by establishing reading-rooms, trades, industrial exhibitions, &c., and by the encouragement of athletic sports to occupy spare time, and already good results have been produced.

The establishment of trades, especially, which will not only interest the soldier but benefit him pecuniarily, is a matter of great importance. It has long been asked why an army should not do all its own work; give the men the hope and opportunity of benefiting themselves, and *ennui* would no longer exist. In India Lord Strathnairn did most essential service by the establishment of trades; and the system, after long discussion and many reports, is now being tried in England.

One of the proofs of ability for command and administration is the power of occupying men, not in routine, but in interesting and pleasant work, to such an extent that rest and idleness may be welcomed as a change, not felt as a burden. Constant mental and much bodily movement is a necessity for all men; it is for the officers to give to their men an impulse in the proper direction.

The last point which probably makes the soldier's life less healthy than it would otherwise be is the depressing moral effect of severe and harassing discipline. In our own army in former years it is impossible to doubt that discipline was not merely unnecessarily severe but was absolutely savage. An enlightened public opinion has gradually altered this, and with good commanding officers the discipline of some regiments is probably nearly perfect, that is to say, regular, systematic, and unfailing, but from its very justice and regularity, and from its judiciousness, not felt as irksome and oppressive by the men.

The general result of the life at home on soldiers must now be considered.

It is by no means easy to say whether soldiers enjoy as vigorous health as the classes from which they are drawn; the comparison of the number of sick, or of days' work lost by illness by artisans, cannot be made, as soldiers often go into hospital for slight ailments which will not cause an artisan to give up work. The comparative amount of mortality seems the only available test, though it cannot be considered a very good one.

SECTION I.

ARMY STATISTICS.[1]

At the close of the Peninsular war in 1814 Sir James M'Grigor commenced the collection of the statistics of disease and mortality in the English army, and during the course of the next twenty years a great amount of valuable evidence was accumulated. In 1835 Dr Henry Marshall (Deputy Inspector-General of Hospitals, and one of the most philosophical surgeons who has ever served in the English army) commenced to put these returns into shape, and the late Major-General Sir Alexander Tulloch, K.C.B. (at that time a lieutenant in the 45th Regiment, employed in the War Office),

[1] This short summary of the history of the Army Statistical Reports is chiefly taken from Dr Balfour's account, in the *Army Medical Report* for 1860, p. 131.

was associated with him. In the following year, on the retirement of Dr Marshall, Dr Balfour, formerly head of the Statistical Branch of the Army Medical Department, was appointed as his successor, and in conjunction with Sir A. Tulloch brought out the series of reports on the health of the army which have had such influence, not merely on the cause of the sickness and mortality among soldiers, but indirectly on those of the civil population also. In 1838–41 reports were issued of the following stations:—United Kingdom, Mediterranean, and British America, West Indies, Western Africa, St Helena, Cape, Mauritius, Ceylon, and Tenasserim.

These returns included the years 1817–1836. In 1853 another report, containing the stations of the troops in the United Kingdom, Mediterranean, and British America, including the years 1836–1846, was prepared by the same gentlemen.

In these reports, in addition to the statistical analysis, short but most graphic and comprehensive topographical and climatic accounts of the different stations were given.

The effect of these several reports, and especially of the earlier issues, was to direct the attention of the Government both to the fact of an enormous sickness and mortality, and to its causes, and then commenced the gradual series of improvements which at a later period were urged on by Lord Herbert with so much energy.

The Russian war of 1854–1855 prevented any further publication until 1859, when yearly reports were commenced by Dr Balfour, and have been regularly issued since. In the report for 1860 Dr Balfour gave a summary of the earlier and later mortality of the different stations before and after 1837, which showed a remarkable difference in favour of the later periods as regards both sickness and mortality.

SUB-SECTION I.

With respect to soldiers, *in time of peace*, the statistical evidence is required to show the amount of benefit the State receives from its soldiers, and the amount of loss it suffers yearly from disease. Tables should therefore show—

1. The amount of loss of strength a definite number of men in each arm of the service suffers in a year—

(*a*) By deaths, or, in other words, the mortality to strength.

(*b*) By invaliding from disease,[1] for if this is not regarded, different systems and modes of invaliding may entirely vitiate any conclusions drawn from the mortality.

The groups thus formed must be again subdivided, so as to show—

(*a*) The *causes* of death or invaliding.

(*b*) The *ages* of those who die or who are invalided.

(*c*) Their *length* of service. It is of great importance to determine the influence of service in every year, and these groups should be again divided by ages.

2. The *loss of effective service* a definite number of men—say, 1000 men in each arm—suffers during a year. This is best expressed as follows:—

(*a*) *The total number of cases of disease* in a year, *i.e.*, the number of ad-

[1] Loss by purchase of discharge, expiration of term of service, imprisonments, and dismissals from the army, must also be put under separate headings; but the medical officer has nothing to do with this point, except to see that such cases are not confounded with invaliding from disease.

missions to hospital per annum. It must be understood that this does not express the number of men admitted, as one man may be admitted two, three, or even ten times with the same disease: each admission counts as a fresh case. It is important to have another table showing the number of men admitted for different diseases, or, in other words, the number of cases of readmission for the same disease. The actual number of *cases treated* in a period may be obtained from the mean of the admissions and discharges.

(*b*) The *number constantly sick* on an average. This is often called the sick population, and is obtained most easily in army hospitals by dividing the number of diets issued in a year by 365, or adding all the "remaining" on the daily or weekly states together, and dividing by 365 or 52, as the case may be.

(*c*) The total number of days lost in a year to the service by illness by each 1000 men, and the number of days per head. The number of the sick population (that is, the number constantly sick out of say 1000 men) multiplied by 365 and divided by 1000, or by the number furnishing the sick, whatever that may be, gives these facts.

(*d*) The mortality in relation to sickness.

The group constituted by the sick must then be subdivided by diseases, and lesser groups must be made by distributing the causes of sickness and deaths under ages and length of service.

There are a few points which require attention. The amount of sickness and mortality is calculated on the mean strength, that is, the number of men of a regiment present at a certain station on the muster days divided by the number of muster days. But it must be understood that this includes the sick men in hospital as well as the healthy men, and therefore does not perfectly express the amount of disease among the healthy men. Also sometimes the muster rolls of a regiment include men on detachment at some distance, whose sickness is not attributable to the headquarters station. The French, in their Army Statistical Returns, make two headings, one of "mean strength" (*effectif moyen*), and the other of "present" (*présents*), the men in hospital not being included in the latter. Moreover, in the French Army nearly one-sixth are always absent on leave; and the deaths of those on leave are included among the army deaths, but the sickness is not so. Consequently sickness has to be calculated on the number not on leave; deaths, on the total strength. In the French army officers are included with the men; in the English, separate returns are made.

It is often difficult to get the mean strength if there are many changes of troops, and instances of erroneous calculations from this cause are not uncommon.[1]

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[1] The following is one which Dr Balfour has given. It will be seen that an unhealthy station (Masulipatam) in India is credited with a much greater degree of health than it really was entitled to, and the annexed extract from Dr Balfour's paper (*Edin. Med. and Surg. Jour.*, No. 172) shows clearly how the mistake arose:—

"The [Madras] Medical Board, in submitting to Government the table from which these figures are computed, stated that the ratio of mortality among all the European regiments in the Presidency, from January 1813 to December 1819, was 5·690 per cent.; whilst that of the regiments at Masulipatam, from 1813 to 1832 inclusive, was 5·100 per cent. They then add—'The rate of mortality having been somewhat lower than throughout the rest of the Presidency for such a period, gives reason to conclude that the station cannot be considered under ordinary circumstances as unhealthy.' Now, the Board appears to have arrived at this conclusion from an error in the mode of calculating the ratio. In several of the years between 1813 and 1832 the regiments were quartered at Masulipatam during part of the year only. It must be obvious to any one conversant with the principles of statistics that in such a case a proportion of the annual strength only should be taken corrresponding with the period for which the regiment was quartered there. Thus, if the period was nine months, the sickness and mortality should be calculated on three-fourths of the strength; if eight months, on two-thirds, and so forth. The Board, however, have made the calculation in

In calculating also the effect of age and length of service upon disease and mortality, it is necessary to know not only the ages and length of service of the sick men, but of the healthy men also, and to calculate out the proportion of the sick to the healthy at that particular age or length of service, otherwise very erroneous conclusions might be drawn. For example, it might appear that sick men under twenty years of age were very numerous in proportion to other years, but in a very young army the greater number of the force might be of this age. Care is necessary in all these points to arrive at correct conclusions.

Sub-Section II.—Statistics in War.

In time of war the statistics must be slightly altered in form, though the same in principle. The object is to show as completely as possible to the General in command what amount of loss his army is suffering at the moment, and to what extent it may be expected to suffer, and also what are the causes of such sickness.

The sickness here must not only be calculated on the mean strength (which will include the men in hospital), but also on the healthy men, or those actually under arms and effective. If the sick are counted in the strength, the sickness of the army may be much understated. What a General wants to know with regard to sickness will be these points—

1. How many men am I losing daily from the rank and file actually serving with the colours?
2. How many are replaced by discharge from hospital?
3. What is the balance, gain or loss?
4. If my effective force loses daily, when this balance is struck, such a percentage, what will be its loss of strength in a week, in four weeks, in six weeks? &c.
5. What are the causes, *i.e.*, what are the diseases which are causing this sickness, and how are they affected by special circumstances of age, particular service or arms, or other causes?

The mortality in war should be calculated on the mean strength, that is, on the total number of healthy and sick, and also on the sick alone, so as to represent both the loss of the army and the fatality of the sickness.

SECTION II.

THE LOSS OF STRENGTH BY DEATH AND INVALIDING, PER 1000 PER ANNUM.

A. By Death.

It is to be understood that the mortality is here reckoned on the strength, that is, on the total number of healthy and sick persons actually serving during the time. The mortality on the sick alone is another matter.

From the Parliamentary Statistical Returns of the Army (1840 and 1853, which include the years 1826–1846), we find that the mortality among the cavalry of the line was at that time about $\frac{1}{3}$d more than among the civil

every instance on the average annual strength without any such deduction. Had the necessary correction been made, the deaths from 1813 to 1832 would have been found to average 6·394 per cent. annually, instead of 5·100 as above stated."

male population at the same age (nearly 15 to 10[1] per 1000); among the foot guards it was more than double (very nearly $20\frac{1}{2}$ per 1000 as against 10); among the infantry of the line it was $\frac{4}{5}$ths more (or 18 per 1000 as against 10).

The State was thus losing a large body of men annually in excess of what would have been the case had there been no army, and was therefore not only suffering a loss, but incurring a heavy responsibility.

In the splendid men of the Household Brigade, diseases of the lungs (including phthisis) accounted for no less than 67·7 per cent. of the deaths, in the cavalry of the line for nearly 50 per cent., and in the infantry of the line for 57 per cent.; while among the civil population of the soldier's age the proportion in all England and Wales was only 44·5 per cent. of the total deaths. The next chief causes of death were fevers, which accounted in the different arms of the service for from 7 to 14 per cent. of the total deaths. The remainder of the causes of deaths were made up of smaller items.

These remarkable results were not peculiar to the English army. Most armies did, some still do, lose more than the male civil population at the same age. The following are the most reliable statistics:[2]—

	Army Loss per 1000.
France (1823),	28·3
France (Paixhans, 1846),	19·9
France,[3] mean of 19 years (1862–82),	9·53
France (1882),	8·75
French in Algeria (1846),	64
,, ,, (1862–82),[3]	15·16
Prussian[4] (1846–1863, excluding officers),	9·49
Prussian (1869),	6·10
Prussian army (including the Saxon and Würtemberg corps, 1876),	4·96
Prussian (1874–81),	4·95

	Army Loss per 1000.
Russian (series of years),	39
,, (1857–1866),	18·7
,, (1871–84),	14·23
,, (1880–81),	10·60
Austrian,	28
,, (1869),	11·58
,, (1876–81),[5]	10·30
Piedmontese (1859),	16
Italian (1870),	8·40
United States (before the war),	18·8
Portuguese (1851–53),	16·5
Danish,	9·5

The old Hanoverian army was very healthy, losing only 5·3 per 1000 as against 9·5 among the civil population of the same ages.

In these foreign armies the same rule holds good; fevers (chiefly enteric in all probability) and phthisis were the great causes of mortality. In Prussia phthisis formerly caused 27 per cent. of the total mortality, but in that army phthisical men are sent home, and after a certain time are struck off the rolls, so that the army deaths are thus fewer than they would be if the men died at their regiments. In Austria phthisis caused 25 deaths out of every 100; in France 22·9,[6] while in 1859 the proportion among the civil population was 17·76; in Hanover, 39·4; and in Belgium, 30; though in the latter country the proportion among the civil population was only 18·97 deaths from phthisis per 100 of all deaths. In

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[1] In reality the deaths from the civil male population of the soldiers' ages (20 to 40) were below ten, and in the healthy districts much below; the case against the soldier is, therefore, even worse than it reads in the text.

[2] Meyne, *Eléments de Stat. Méd. Militaire*, 1859, gives some of these figures; others are taken from the reports of the different armies.

[3] 1870–71 omitted.

[4] Dr Engel, in *Zt. des Königl. Preussich. Stat. Bureaus*, Aug.–Sept. 1865, p. 214.

[5] If we omit 1879, an exceptional year, the mean is only 9·40.

[6] This was in 1860; calculated from Laveran's returns from eleven of the great garrisons. In the whole French army (including Algeria, Tunis, &c.) the mean for 10 years (1873–82) was 26·5 per 100 deaths.

Portugal the mortality from phthisis constituted 22 per cent. of the deaths,[1] while in the civil population the deaths are 12 per cent. of the total deaths. In the Prussian army in 1876 only 16 per cent. were from phthisis. In these armies, also, fevers caused a greater number of the deaths than in the English army, even in the period referred to. In Prussia, 36 (reduced in 1876 to 20); in France, 26;[2] in Belgium, 16·6; and in Hanover, 23·68 per cent. of all deaths were from fever (enteric?). In Portugal only 3·9 deaths are from enteric fever out of every 100 deaths; this is owing to its rarity in the country districts; it is common in Lisbon.

Nothing can prove more clearly that in all these armies the same causes were in action. And from what has been said in previous chapters, it may be concluded that the reason of the predominance of these two classes—lung diseases and enteric fever—must be sought in the impure barrack air and in the defective removal of excreta.

The Crimean war commenced in 1854 and ended in 1856. A large part of the first army was destroyed, and a fresh force of younger men took its place. Soon afterwards the great sanitary reforms of Lord Herbert commenced. In 1859 yearly statistical returns began to be published.

The mortality of all arms has undergone an extraordinary decrease from that of the former period.

Mortality per 1000 *per Annum in United Kingdom.*

	From all Causes.	From Disease alone (*i.e.*, excluding violent death).
Mean of ten years, 1861–70, .	9·45	8·534
,, ,, 1870–79, .	8·18	
,, five years, 1879–83, .	7·01	6·030
1884, .	5·33	4·660

The diminution over the years previously noted (1826–46) is extraordinary. Three causes only can be assigned for it—the youth of the army and a better selection of men; or a partial removal of the causes of diseases; or earlier invaliding, and the action of the Limited Enlistment Act, so as to throw the fatal cases on the civil population.

The question of age has been examined and disposed of by Dr Balfour,[3] who has shown that the youth of the army does not account for the lessening. Selection has always been made with equal care; and invaliding, though it certainly has been greater of late years, does not appear to have been in excess sufficient to account for the lessening. There can be no doubt, then, that the great result of diminishing by two-thirds the yearly loss of the army by disease has been the work of Lord Herbert and the Royal Sanitary Commission.

It will be observed that the amount of the mortality in the French army was also singularly lessened from 1846 to 1862 and 1863 and later years, and this is, no doubt, owing to the great sanitary precautions now taken in that army.

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[1] Marques, reviewed in an excellent article in the *British and Foreign Medico-Chir. Review* for April 1863.

[2] Laveran, in 1860, made the number 25·9 in the deaths from eleven garrisons. In 1863 the mortality from enteric fever in the French army was 1·87 deaths per 1000 of effectives in France, 1·63 in Algeria, and 3·55 in Italy. In 1866 the mortality was 1·45 in France, 1·39 in Algeria, and 2·26 in Italy. In 1873–82, for the whole French army, the deaths were 38·1 per cent. of total deaths, or about 3·5 per 1000 of strength; this, however, includes the enormous losses in Tunis in 1881. The years 1880 and 1882 were also exceptional (Morache).

[3] *Army Medical Reports* for 1859, p. 6.

Of the different arms of the service, the cavalry and artillery are rather healthier than the infantry; the engineers than either; the officers always show less mortality than the non-commissioned officers and privates, and the non-commissioned officers less than the privates. In different regiments there is often a singular difference in the mortality in a given year, but this is usually easily accounted for, and in a term of years the differences disappear.

Comparison with Civil Population.

This gross mortality must now be compared with that of the civil population. In England the gross male civil mortality at the soldier's age is—

	Mortality per 1000 of Population.
From 20 to 25 years of age,	8·83
25 to 35 ,,	9·57
35 to 45 ,,	12·48

The soldier's mortality, taken as a whole, is therefore under that of the civil population, but then there is invaliding, and some uncertain addition should be made to the mortality on this account.

Comparing the soldier's mortality (for a ten years' period, and invaliding being disregarded) with trades, he is now healthier than carpenters (7·77), labourers (7·92), bakers (7·94), blacksmiths (8·36), grocers (8·4), farmers (8·56), weavers and cotton-spinners (9·1), shoemakers (9·33), butchers (9·62), miners (9·96), tailors (11·62), and publicans (13·02),[1] in fact, than all trades with which that of the soldier has been compared. Formerly the case was different, several trades showing less mortality than that of the soldier.

Influence of Age on the Mortality.

The following table gives the results :[2]—

	Per 1000 of Strength.					
	Under 20.	20 and under 25.	25 and under 30.	30 and under 35.	35 and under 40.	40 and upwards.
1873-82 (10 years),	3·21	4·82	6·29	10·34	15·82	22·91
1884, . . .	2·39	4·47	5·68	10·15	11·78	19·85
Civil male population in England and Wales,	6·89	8·67	9·55	10·37	11·96	13·96
Healthy districts,	5·83	7·3	7·93	8·36	8·96	9·86

The number of soldiers under 20 years of age is so small that no conclusions can be drawn; but it would appear that from 20 to 30 the mortality is favourable to the soldier, but after that the proportion is reversed, and the soldier dies more rapidly than the civilian. And if to this we call to mind the invaliding from the army, it seems clear that a prolonged military career is decidedly injurious, either from causes proper to the career or to personal habits engendered in it.

Causes of Mortality.

In order to see the principal causes of the eight or nine deaths which occur annually among 1000 men, the following table has been calculated from the *Army Medical Reports* :—

[1] Dr Farr's numbers, in the *Supplement to the 25th Report of the Registrar-General*, p. xvi.
[2] *Army Medical Reports*, vol. xxii., 1882, p. 30.

Causes of Mortality.[1]

	Mortality per annum per 1000 of Strength (1867–71, 5 years).	Deaths in 100 Deaths (1867–71, 5 years).	Mortality per annum per 1000 of Strength (1872–80, 9 years).	Deaths in 100 Deaths (1872–80, 9 years).	Mortality per annum per 1000 of Strength (1879–83, 5 years).	Deaths in 100 Deaths (1879–83, 5 years).
Phthisis and tubercular hæmoptysis	2·648	30·26	2·29	29·0	2·14	30·5
Diseases of heart and vessels,	1·462	16·71	1·17	14·8	0·72	10·3
Pneumonia,	0·777	8·88	1·34[2]	17·0[2]	1·38[2]	19·7
Violent deaths,	0·598	6·84	0·61	7·7	0·87	12·4
Diseases of nervous system,	0·576	6·58	0·54	6·8	0·46	6·6
Continued fevers, chiefly enteric,	0·405	4·63	0·30	3·8	0·32	4·5
Suicides,	0·288	3·30	0·21	2·7	0·23	3·3
Bronchitis,	0·167	1·91	...[2]	...[2]	...[2]	...[2]
Delirium tremens,	0·069	0·80	...[2]	...[2]	...[2]	...[2]
All other causes,	1·756	20·07	1·42	18·2	0·89	12·7

This table must now be analysed more particularly.

1. *Tubercular Diseases.*

The deaths from phthisis and hæmoptysis in the eight years ending 1866 averaged 3·1 annually per 1000 of strength, the highest annual ratio being 3·86, and the lowest 1·95. In 1867–71 the mean mortality was 2·648 per 1000, in 1872–80, 2·29; in 1879–83, 2·14. In addition to this there was invaliding for phthisis, and thus a certain number of deaths were transferred from the army to the civil population. The following table shows the exact number in four branches of the service (two cavalry and two infantry) in seven years :—

TABLE *to show the Deaths and Invaliding per annum from Phthisis and Hæmoptysis in Household Cavalry, Cavalry of the Line, the Foot Guards, and Infantry of the Line (mean of seven years,* 1864–70).

Phthisis and Hæmoptysis, taken from Abstract in Appendix to Dr Balfour's Report.	Household Cavalry.	Cavalry of Line.	Foot Guards.	Infantry of Line.
Died per 1000,	3·763	1·416	2·300	2·120
Invalided per 1000,	8·234	4·025	9·491	5·510
Total died and invalided per 1000,	11·997	5·441	11·791	7·630

This table shows a considerable difference between the branches of the service; the mortality and invaliding of the household troops are much the highest. The mortality from tuberculosis of the infantry of the line is below the mean mortality of the army at large; the mortality of the cavalry of the line below that of the infantry.

[1] This table has been calculated from the numbers in the *Army Med. Department Blue Books* (1867–84).

[2] The abridged and incomplete form in which the statistics have been published since 1874 render it impossible to give these numbers in detail. The numbers opposite *pneumonia* for the later period include all diseases of the Respiratory System, and the deaths from *delirium tremens* are included under the head of Poisons.

Since 1881 some more details have been given, so that we can state the ratios for 4 years (1881–4): deaths from pneumonia, 0·90 per 1000 of strength, bronchitis, 0·16, pleurisy, 0·10.

It is quite clear (and the same thing is seen in the earliest records) that there has been an excessive rate of mortality and invaliding from phthisis in regiments serving in London, which points to some influences acting very injuriously upon them. During the later years, however, the invaliding in the foot guards has decreased, although the mortality has not diminished. It is remarkable that a similar excessive mortality has been observed in the guard regiments of both France and Prussia, located respectively in Paris and Berlin.[1] The following table shows the average of our own army up to 1876:—

Table similar to one on page 564, *for* 6 *years* 1871–76.

Phthisis, &c.	Household Cavalry.	Cavalry of Line.	Foot Guards.	Infantry of Line.	Depôts. 1873–76.
Died per 1000, .	3·33	1·46	2·43	2·15	4·18
Invalided per 1000,	4·44	4·30	7·17	4·60	9·82
Total died and invalided per 1000,	7·77	5·76	9·60	6·75	14·00

From this table it may be seen that up to 1876 there was a slight diminution of mortality in the household cavalry and in the infantry of the line, but that the rates were nearly stationary in the cavalry of the line and the foot guards, and very high in the depôts. In the invaliding the rates were decidedly lower in the household cavalry, the foot guards, and the infantry of the line, whilst there was a slight increase of the cavalry of the line, and the rate was high in the depôts.

Unfortunately since 1876 this information is no longer available, it being omitted from the *Army Medical Reports.*

How does this mortality compare with that of the male civil population at the soldiers' ages?

Mortality from Phthisis.

Male Civilians.[2]	Age.	
All England and Wales, ...	20 to 25	3·50
,, ,, ...	25 ,, 30	4·00
,, ,, ...	30 ,, 35	4·10
,, ,, ...	35 ,, 40	4·10
,, ,, ...	15 ,, 55	3·70
,, ,, ...	25 ,, 45	4·02
London, ...	15 ,, 55	4·50
Worst districts in England, excluding hospitals, .		5·00
Best districts in England, ...		1·96

The deaths in the army from phthisis and hæmoptysis are less than the deaths in the population generally. They are, however, on an average greater than in the best districts in England, although the rate for 1884 (viz., 1·79) was distinctly less. But in the army there is invaliding also; that is, men with a fatal disease are discharged into the civil population. In 1884 there were invalided for tubercular disease 2·73 per 1000, and this added to the deaths (1·79) gives 4·52 as the ratio of loss from that class of disease. Taking this into consideration, it seems certain that phthisical disease is still in excess in the army as compared with the male civil population.[3]

[1] Roth and Lex, *op. cit.*, vol. iii. p. 392.

[2] Parliamentary Return of *Annual Average Mortality during the Decennial Period* 1851–60, Feb. 1864; and Dr Farr's *Report to the Sanitary Commission*, p. 507.

[3] The total deaths and invaliding for the 5 years 1879–83 amounted to 6·15 per annum.

Did the army suffer more from phthisis in former years than it does now? The following table will answer this question:—

Deaths from Phthisis per 1000 of Strength.

	Years 1830–36, =7 years.	Years 1837–46, =10 years.
Household Cavalry,	7·4	6·28
Cavalry of the Line,	5·29	5·65
Foot Guards,	10·8	11·9
Infantry,	...	7·75
Mean,	7·83	7·89

During these two periods, which make a total of seventeen years, the mortality was 7·86 per 1000, and there was no decline in the later as compared with the earlier period.

But as in the 8 years ending with 1866 the mortality was only 3·1 per 1000, in the 5 years ending 1871 only 2·6, in the 9 years ending 1880 only 2·3, in the 5 years 1879–83 only 2·14, and in the year 1884 itself only 1·79 per 1000, giving for the whole period of 26 years only 2·5, there must have been an enormous excess of mortality in the earlier period, unless it can be explained in some way.

(*a*) In the earliest periods the mortality from chronic bronchitis was included in the phthisical mortality. If a correction is made for this, the mortality of the period 1859–1880 would not reach 3·0; so that will not explain the difference.

(*b*) Was the invaliding more active in the last period, so as to lessen the deaths occurring in the army below what would have taken place without invaliding? The information about the early periods is scarcely obtainable, but there seems no reason to think it was less than subsequently, but on the contrary, it was very large from the foot guards. That invaliding cannot account for the difference is seen by the fact that the annual deaths per 1000 in the seventeen years ending 1846 (viz., 7·86) were more numerous (in the cavalry and infantry of the line) than the average of deaths and invaliding together in the period of five years ending 1871.

(*c*) The Limited Enlistment Act, by which a certain number of weakly men may possibly have left the army, was in action in the last period. It is impossible to estimate the amount of this action, but it is in the highest degree improbable that it had much direct effect; for if a man of nearly ten years' service were ill with phthisis, he would be sure to get invalided, in order to enjoy his temporary pension for two or three years, and would not simply take his discharge.

(*d*) The lessened age of the army at large might perhaps have some effect, as mortality from phthisis increases with age in the French army, and probably in our own; but this would never account for the astonishing difference; for in the French army the increase from phthisis of the men over fourteen years' service, as compared with those under, is only 1 per 1000 of strength.

We may conclude, then, that there was a greater excess of the disorganising lung diseases classed as phthisis in the earlier period (1830–46). The amount of phthisis strongly attracted the attention of Sir Alexander Tulloch and Dr Balfour in 1839. They state that in the Equitable Assurance Company at that time the annual mortality (at the ages 20 to 40) from disease of the lungs was 3·4 per 1000; while in the years 1830–36 the mortality from

disease of the lungs among the foot guards was no less than 14·1 per 1000, of which phthisis alone caused 10·8.[1]

How does our army contrast with others?

In France[2] the deaths from phthisis and chronic bronchitis together amount to 2·86 per 1000 of "present," so that it is probable that there is at present even more phthisis in the French than in our own army. In the Prussian army the men are also discharged early, so that comparison is difficult.

In the Prussian army the mean yearly mortality from laryngeal and lung phthisis was 1·28 per 1000 of strength (years 1846–63); in 100 deaths there were 13·57. What the amount of invaliding was at that time does not appear to be recorded, but in 1868–9 it was about 3 per 1000 of strength.[3]

We may conclude, then, with regard to phthisis—

1. That it was formerly in enormous excess in the army over the civil population, and particularly in the foot guards; in other words, a large amount of consumption was generated.

2. That there has been a great decline of late years, though there is still in all probability some excess, especially in the household troops.

What are the causes of this phthisical excess in the years 1830–46? It is noticeable that in the earlier periods all affections of the lungs were also in excess, and we can readily see that a number of antecedents may combine in producing the result, and that destructive lung diseases may proceed from many causes. Still there must have been some predominating influence at work.

The phthisis was not owing to climate, for that is unchanged. Moreover, we shall hereafter see that the same excess was seen in the Mediterranean stations and the West Indies.

It was not owing to syphilis, for until late years the amount of syphilis has rather increased than diminished, while phthisis has lessened.

It was not owing to bad food, for the food was the same in all the branches, and yet the amount of phthisis was widely different. Besides, the food has been comparatively little altered.

It can hardly have been the duties or clothing,[4] for there has been no sufficient change in either to account for the alteration, unless the abolition of one of the cross-belts some years ago had some effect. But then this would have only affected the infantry.

It must have been some conditions acting more on the foot guards than in the household cavalry, and less in the line regiments; also it must have been acting in the troops stationed in the Mediterranean and the West Indies. There is only one condition common to all which seems capable of explaining it, and that the cause noticed in the Report of 1839, viz., overcrowding. This condition was and is still most marked in the barracks of the foot guards, and least in the barracks of the cavalry of the line. It is

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[1] In commenting on this fact the reporters say (*Army Medical Reports* of 1839, p. 13)—'If the aggregation of a number of men into one apartment, even though the space is not very confined, creates a tendency to this disease, then it clearly points out the propriety of affording the soldier as ample barrack accommodation as possible." Thus, even at that time, it was seen that no other cause but overcrowding could account for the great amount of lung disease.

[2] Mean of ten years, 1873–82 (Morache). [3] Roth and Lex, *op. cit.*, vol. iii. p. 391.

[4] Dr Lawson has, in a very able paper read to the Statistical Society (Jan. 1887), attributed the increase of phthisis from 1823 to 1846 to the effects of the introduction of white trousers in the former year; the amelioration after 1846 to the substitution in that year of serge trousers; and the further improvement of still later times to the introduction of the flannel shirt.

the only condition which has undergone a very decided change both at home and abroad. This consideration, as well as those formerly noticed in the section on AIR, seems to make it almost certain that the breathing the foul barrack atmosphere was the principal, perhaps the only, cause of this great mortality from lung diseases. If this be so, it shows that the foot guards are still the worst housed of any troops.

2. *Diseases of the Heart and Vessels.*

The fact that diseases of the circulatory system so long ranked second as causes of death in the army at home may well surprise us. It was marked in all arms, as much in the artillery and cavalry as in the infantry. The ratio per 1000 of strength for the five years 1867–71 for all diseases of the organs of circulation was 1·462, and in those years out of every 100 deaths no less than 16·7 were from disease of the heart and vessels. In addition, there was a large amount of invaliding from this cause.

If the fatal diseases of the circulatory system of the five years 1867–71[1] are divided into two classes, those referred to some disease of the heart itself (chiefly chronic), and those referred to aneurysm (including an occasional rare return headed "Degeneratio Aortæ"), it is found that the deaths are :—

	Per 1000 of Strength.	In 100 Deaths.
From cardiac disease, . .	0·727	8·31
From aneurysm, . . .	0·735	8·4
Total, . . .	1·462	16·71

These numbers are higher than those of the nine years (1859–67), when the mortality from circulatory diseases was only 0·908 per 1000 of strength, and the percentage on the total deaths was 9.

This mortality is in excess of that of the civil male population of the same age, especially as regards aneurysm. Dr Lawson calculated that aneurysm was eleven times more frequent among soldiers than civilians; and he also calculated that among civilians, aged 15 to 44, the ratio of mortality from cardiac affections alone is 0·45 per 1000. The army, then, in the years 1867–71, had an excess of 0·277 per 1000 of heart disease. Myers' statistics are confirmatory. The amount of heart disease was greater among the foot guards than among the metropolitan policemen. Myers in his able treatise[2] gives the following numbers :—

	Died per 1000.	Invalided per 1000.
Foot Guards, ...	0·8	3·2
Police, ...	0·29	1·37

It was greater among soldiers than sailors; from six years' observations (1860–65) Myers[3] makes the navy mortality 0·66, and the invaliding 3·44 per 1000; while in the army in the same years the mortality was 0·9, and the invaliding 5·26.

If the different arms of the service are taken, the following numbers are given by the five years 1867–71 :—

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[1] In the recent returns the differential diagnosis is not given. In the nine years 1872–80 the deaths per 1000 from diseases of the circulatory system were 1·17, and the percentage of total deaths 14·8. In the five years 1879–83 the numbers were respectively 0·72 and 10·3; in 1884 they were 0·38 and 7·1.

[2] *Diseases of Heart among Soldiers*, by A. B. R. Myers, Coldstream Guards. London, 1870.

[3] *Ibid.*, p. 11.

	Cavalry of Guard.	Cavalry of Line.	Artillery.	Foot Guards.	Infantry of Line.
Mean yearly strength, . .	1,213	8,468	9,417	5,749	31,729
Total deaths from disease of the heart in five years, . .	1	24	57	19	73
Total deaths from aneurysm in five years, ...	2	37	49	20	103
Heart deaths per 1000 of strength,	0·181	0·566	1·210	0·661	0·460
Aneurysmal deaths per 1000 of strength, per annum, . .	0·329	0·873	1·041	0·695	0·649

The numbers in the household cavalry are so small, it is not safe to use them; but the other numbers are sufficiently large to render it probable that the artillery show a larger proportion of fatal cardiac and aneurysmal cases than any other body of troops. The line cavalry and line infantry both show rather an excess of aneurysmal over heart deaths; while the artillery show more heart than aneurysmal deaths, and in the foot guards the proportion is equal. The point which comes out clearly from the table, in addition to the large amount in all, is the excess of both classes of deaths in the artillery; that it is a real excess is seen by comparing the yearly number of the artillery and cavalry of the line, who did not differ greatly in mean strength. The production of these diseases of the circulatory organs begins very early in the military career. In 1860–62 Dr Parkes calculated out the causes of invaliding in 6856 men. Of these 1014 were under two years' service. In the whole number the percentage of heart and vessel disease as the cause of the invaliding was 7·7; among the men under two years' service it was 14·23 per cent. As these men had presumably healthy hearts when they enlisted, the effect both of the military life in producing diseases of the circulatory organs, and the greater suffering from it of young soldiers, seems certain. The statistics in the Knapsack Committee's Report confirm this.

The cause of this preponderance in the army of diseases of the circulatory organs is a matter of great importance. Whatever they may be, it is probable that they produce both the cardiac and the arterial disease.

The two most common causes of heart disease in the civil population are rheumatic fever in young, and renal disease in older persons. The latter cause is certainly not acting in the army, and the former appears quite insufficient to account for the facts. A great number of the men who suffer from heart and vessel disease have never had acute rheumatism; and if we refer the affection to slight attacks of muscular rheumatism, which almost every man has, we are certainly going beyond what medical knowledge at present warrants. The effect of lung disease in producing cardiac affections is also not seen in the army to any extent.

The influence of syphilis in producing structural changes in the aortic coats was noticed by Morgagni. In 114 *post-mortem* examinations of soldiers dying at Netley, Dr Davidson[1] found 22 cases of atheroma of the aorta. Of those 17 had a syphilitic history, 1 was doubtful, and 4 had had no syphilis, but had heart and lung diseases. Of the whole 114 cases, 78 had no syphilitic history and had 4 cases of atheroma, or 5·1 per cent.; 28 had a marked syphilitic history and 17 had atheroma, or no less than 60·7 per cent. This seems very strong evidence as to atheroma. With respect, however, to actual aneurysm, no corresponding analysis of cases has been made, and therefore at present the effect of syphilis must be considered

[1] *Army Medical Department Reports*, vol. v. p. 481.

uncertain; but it is quite clear, even admitting its influence, there is no reason to think that syphilis prevails more among soldiers than among the civil male population of the same class. It is, therefore, unlikely that an excess of syphilis, if it really occurs among soldiers, and if it actually predisposes to aneurysm, as seems probable, could produce 11 times as many aneurysms as in civil persons. Myers has also given evidence that both in the army and navy aneurysm is sometimes not preceded by degeneration of the arterial coats, and in these cases mere improper exertion seemed to produce it.

The effect of excessive smoking again has been assigned as a cause of the soldier's cardiac disease; but no one who knows the habits of many continental nations, and of some classes among our own, could for a moment believe this to be the cause.

Again, the effects of alcohol in constantly maintaining an excessive action of the heart are so marked as to make it highly probable that this is a fact of great importance; but soldiers do not drink so much, as compared with civilians, as to lead us to think the cause can explain the prevalence.

There is, however, one cause which is continually acting in the case of soldiers, and that is the exertion (often rapid and long continued) which some of the duties involve.[1] The artillery have very heavy work; often it is very violent and sudden, more so perhaps than in any other corps; the cavalry also have sudden work at times; and the infantry soldier, though his usual labour is not excessive, is yet sometimes called upon for considerable exertion, and that not slowly, or with rests, but with great rapidity. And this exertion is in all arms undertaken with a bad arrangement of dress and of equipments. The cavalry and artillerymen are very tightly clothed, and though the horse carries some of the burden, it is undoubted that the men are overweighted. In the infantry, till lately, they wore very tight-fitting tunics, with collars made close round the neck, and trousers (which were often kept up by a tight belt); there was a broad strap weighted below with a heavy pouch and ammunition, crossing and binding down the chest; and there was the knapsack constricting the upper part of the chest, and hindering the air from passing into the proper lobes.

The production of heart disease ought not to be attributed solely to the knapsack, as is sometimes done; the knapsack is only one agency; the cross-belt was probably worse, and the tight clothes add their influence. But even with the knapsack alone the effect on the pulse is considerable, and one or two of Dr Parkes' experiments may be given in illustration. Thus, four strong soldiers carried the old Regulation knapsack, service kit, greatcoat, and canteen, but no pouch and no waist-belt (except in one man). The pulse (standing) before marching was on an average 88; after 35 minutes it had risen on an average to 105; after doubling 500 yards to 139, and in one of the men was 164, irregular and unequal. After the double they were all unfit for further exertion. In a fifth man, who was not strong, the 35 minutes' marching raised the pulse from 120 to 194; after doubling 250 yards, he stopped; the pulse then could absolutely not be felt. In another series, the average pulse of four men, with the knapsack only, was 98 (standing); after one hour's march, 112; after their doubling 500 yards, 141. If the pouch with ammunition is added, the effect is still greater. Dr Parkes also took the pulse and respirations after

[1] For a full and able discussion on all those points, and for additional evidence, reference must be made to Mr Myers' excellent work. On the effect of exertion during war in causing cardiac hypertrophy, reference may be made to Dr Fräntzel's paper in Virchow's *Archiv*, Band lvii. p. 215.

long marches and found the effect still more marked. Walking, of course, will quicken the pulse and respiration in any man, but not to such an extent, and the sense of fatigue in unencumbered men is much less.

In the lecture formerly alluded to,[1] Dr Maclean put this matter most forcibly before the authorities, and he was undoubtedly quite justified in the expression that one cause of the cardiac (and perhaps of the aortic and pulmonary) disease in the army is to be found in exertion carried on under unfavourable conditions.

Happily, much has been lately done by the authorities to remove this cause, with the happy effect, as the returns show, of diminishing the amount of mortality and sickness from this cause; but still, especially in the artillery and mounted service,[2] changes appear to be necessary, and in all arms it is desirable that officers should allow their men to do their work under the easiest conditions, as regards clothes, weights, and attitudes, consistent with military discipline and order.

3. *The Nervous Diseases.*

These form a very heterogeneous class; apoplexy, meningitis, paralysis, mania, &c., are the chief headings. The proportion to 1000 of strength is about 0·46, and 6·6 deaths of every 100 are owing to nervous diseases. As among the male civil population (ages 25 to 35) the deaths are also 6·6 per cent. of total deaths, soldiers do not appear to suffer more.

4. *Pneumonia and Acute Bronchitis.*[3]

TABLE *to show the Admissions and Deaths per Annum per* 1000 *of Strength, years* 1859–71 (*thirteen years*).

	Pneumonia.		Acute Bronchitis.	
	Admissions.	Deaths.	Admissions.	Deaths.
Average, ...	5·25	0·641	55·65	0·227
Highest in thirteen years, .	7·13	0·741	88·00	0·380
Lowest in thirteen years, . .	3·49	0·423	39·10	0·080

The acute inflammatory diseases of the lungs gave, therefore, a mean annual mortality of 0·856 per 1000 of strength. The mean total deaths from diseases of the respiratory system, for the nine years 1872–80 was 1·34 per 1000, causing 17 per cent. of total deaths. In the four years 1881–84 the deaths from pneumonia were 0·90, from bronchitis 0·16, and from pleurisy 0·10 per 1000 of strength.

In the French army pneumonia gives a lower, and acute bronchitis a higher, mortality than in our own, but this is perhaps a mere difference of nomenclature.

The opinion that the military suffer more than the civil population from

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1 *Royal United Service Institution Journal*, 1863, vol. viii.

2 The cardiac diseases are of the most varied kind. Dr Parkes wrote—"I have seen at Netley, in Dr Maclean's wards, in one hour in the summer, when the hospital is full, almost all the combinations of heart affections. It has appeared to me that if anything gives the tendency to heart affections, then the dress and accoutrements come in as accessory causes, and prevent all chance of cure. In some cases there is no valvular disease, and not much hypertrophy of the heart, but a singular excitability, so that the heart beats frightfully quick on the least exertion."

3 Separate data are not published in the *Army Medical Reports* for the later years.

pneumonia is an old one. It is also generally believed that they suffer less in the field than in garrison. Trustworthy statistics seem wanting as to the amount among the civil population. In the European population, generally, Ziemssen[1] gives the deaths from pneumonia as 1·5, and Oesterlen[2] 1·25 per 1000; but this includes all ages and both sexes. Among men alone it is certainly greater than among women. In London, in 1865, the mortality from pneumonia, between the ages 20 and 40 (both sexes), was 1 per 1000 population.[3]

If this be correct, the mortality among soldiers is below the civil mortality, or soldiers are less subject than civilians; for, as men are more subject to pneumonia than women, the mortality among the civilian males would be greater than 1 per 1000, but the military mortality is only 0·641. The mortality among the army pneumonia cases (deaths to treated) amounts (average of thirteen years) to 12·18 per cent.,[4] and as this is very nearly the civil proportion, every 1000 of population in London gave nine cases of pneumonia, while 1000 soldiers gave only five. It may be said, however, that London is not a fair test; but as a place of residence for soldiers it does not appear to predispose to pneumonia, as will be seen from the following table:—

	Per 1000 of Strength, years 1864-71. Foot Guards in London.	Infantry in the Kingdom generally.
Admissions from pneumonia, . . .	3·75	6·06
Deaths from pneumonia, ...	0·44	0·66

The mortality to cases treated in the five years 1867–71 was, in the guards, 10·68, and in the infantry, 11·7 per cent.

Although it does not seem that pneumonia (and acute bronchitis?) are more common or more fatal among soldiers serving at home than among civilians, the above figures show what a fatal disease pneumonia is, and how worthy of renewed study its causes are.

5. *The Class of Continued Fevers.*

The returns now distinguish two groups of continued fevers as *Enteric* and *Other*, the latter including typhus as well as febricula. Practically the majority of the fatal cases of "continued fever" are from enteric fever.

There has been a great decline in this class of late. In the ten years 1837–46 the average admissions were 62, and the deaths 1·72 per 1000 of strength. In the eight years ending 1867 the admissions averaged 22, and the deaths 0·5 per 1000 of strength. In 1871 there were only 80 cases of enteric fever and 22 deaths in the whole army of 87,000 men. In the four years ending 1875 the mean total deaths from continued fever were 0·37 per 1000, and they amounted to 4·4 per cent. of the total deaths. In the five years ending 1880 the mean total deaths were 0·30 per 1000, and the numbers to total deaths 4·1; in the five years 1879–83 the mean deaths were, from enteric fever, 0·18 per 1000, and percentage of total deaths, 2·6; in 1884 the numbers were respectively 0·19 and 3·6.

This mortality is below that of the male civil population of the same age,

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[1] *Monats-Bl. für Med. Stat.*, 1857, and *Schmidt's Jahrb.*, 1862, No. 3, p. 337.

[2] *Med. Statist.*, 2nd edit., p. 567.

[3] Vacher, *Sur la Mort en* 1865, Paris, 1866, p. 137.

[4] In thirteen years there were 4826 cases treated, and 588 deaths, or 12·18 deaths per cent. In Canada the deaths to admissions were only 7·13 deaths per cent. (average of twelve years ending 1870).

which, for enteric fever alone, amounted to 4·4 per cent. of total deaths, and about 0·33 per 1000 of population in 1878, and to 4·1 and 0·301 in 1881.

During late years no points have been more attended to in the army than pure water supply and good sewerage, and we see the results in this very large diminution of death from the rate of the former period, and in the fact that in this particular class of disease the soldier is better off than the civil population. So also the cholera of 1866 passed very lightly over the army at home (only 13 deaths out of 70,000 men),[1] although in former epidemics the army suffered considerably.

The decline of enteric fever confirms most strongly the doctrine of its intimate dependence on bad sewage arrangements.

The greatest amount of enteric fever in the army is in the garrisons and in the seaports, the least in the camps.[2]

6. *Other Diseases.*

The other classes of disease causing mortality need no comment. Chronic bronchitis is no doubt to be chiefly referred to phthisis (using that term as a generic word to include various disorganising lung diseases), and *delirium tremens* is a return which will, no doubt, gradually disappear in fact, as it has already done in *figures*, from the published Reports.

The smaller items of mortality, making up about 22 out of every 100 deaths, are various: erysipelas, pyæmia, syphilis, hepatitis (in men from foreign service), enteritis, rheumatism (from heart complication probably, but returned as rheumatism), diabetes, ebriositas, scarlet fever, and diphtheria are a few of the many causes which carry off a small number every year. The cancerous and kidney diseases are very few, as we might expect from the ages of the men.

To sum up the case as regards the present mortality on home service, it may be stated that for the last twenty-five years (up to 1884) there has been some lessening, but no great fall in the number of deaths. There is still much to be done in respect of preventing disorganising lung disease, disease of the circulatory organs, and even fever, for we ought not to be satisfied until the term enteric fever is altogether obliterated. A renewed study of the causes of pneumonia is also necessary, in order to see if some way or other the attacks of that fatal disease cannot be lessened. There is no reason to think that we have yet touched the lowest possible limit of preventible disease; but, on the contrary, we can see clearly that the soldier, comparatively healthy as he is, may be made more healthy still. Some evidence in support of such a view may be found in the fact, that both at Gibraltar and in some of the West Indian stations the mortality has been lower in some years than it has ever been at home. But there is no reason why the home mortality should not be reduced to the standard of those foreign stations.

A question now arises—Why, after thirty years of age, should the soldier die more rapidly than the civilian, though for the first ten years of his service he has a smaller mortality? The causes may be foreign service, bad social habits (*i.e.*, excess of drinking and syphilis, or other effects of enforced celibacy), night duty, exposure on guard, and prolonged influence of impure barrack air. But to which of these the result is owing could only be determined by accurate statistical inquiries into the causes of mortality at the older

[1] 1·86 per 10,000 living, against 6·7 in total civil population of England and Wales.

[2] In the French army (1879) the deaths from enteric fever are 2·7 per 1000 and about 33 per cent. of all deaths.

ages. We do not know these, and if the short-service system continues we are hardly likely to know them, so it is of no use to discuss a topic on which sufficient facts are not available.

B. Loss of Strength of the Army by Invaliding.

The amount of invaliding is influenced by other causes than mere inefficiency of the men; sometimes a reduction is made in the army, and the opportunity is taken to remove weakly men who would otherwise have continued to serve. This was the case in 1861. As invaliding greatly affects the mortality of the army, a source of fallacy is introduced which it is not easy to avoid.

During the seven years 1860–66 there were invalided every year nearly 37 men out of every 1000, thus making a total loss by death and invaliding from disease of nearly 46 men per 1000, or about one-twenty-second part of the whole force. In 1867 the invaliding was lower, viz., 22·18 per 1000. For the ten years 1870–1879 the invaliding in the United Kingdom was at the rate of 27·18 per 1000, and the deaths were 8·18,—making together 35·36, or one-twenty-eighth part of the force. For the whole army the numbers were, 22·15 and 12·67,—together 34·82, or slightly less. In the five years 1879–83 the invaliding at home was 23·39 and the deaths 7·01, together 30·40; for the whole army, 21·66 and 12·06, together 33·72. In 1884 the total loss for the United Kingdom was only one-thirty-eighth, and for the whole army the same. Speaking in round numbers, phthisis and scrofula account for about one-sixth of the invalids, and if chronic bronchitis were included, for nearly one-fourth; the diseases of the circulatory system account for one-fifth, and chronic rheumatism for one-twentieth. Nervous diseases always cause a large number of invalids, amounting nearly to one-ninth. All the other items were smaller. In men invalided under one year's service, nearly one quarter were from epilepsy; the remaining chief causes were phthisis and diseases of the circulatory organs. It is probable that the loss from invaliding will continue to diminish as a consequence of the short-service system.

SECTION III.

LOSS OF SERVICE FROM SICKNESS PER 1000 PER ANNUM.

(*a*) *Number of Admissions into Hospital.*—On an average, 1000 soldiers furnish rather under 1000 admissions into hospital per annum; 809·1 in ten years (1870–79); 840·2 in 1874–1883; in 1884, 861·7. The number varies in the different arms from about 600 in the household cavalry and engineers, which is usually the lowest, to about 1100 in the cavalry and artillery depôts. In the first case the steady character of the men, many of whom are married, and in the second the frequency of contusions during drill, account for this great range. In the infantry the average is from 850 to 1020.

The number of admissions remained tolerably constant for twenty-five years, but during late years has been sensibly declining, although it is to be feared that the repeal of the Contagious Diseases Acts will in the future affect the ratio unfavourably.

The admissions in the French army are not comparable with ours; slight cases of sickness (which with us are often not recorded) are treated in

barracks (*à la chambre*), severer, but still slight, cases in the infirmaries, bad cases in the general hospitals. The mean of five years (1862–66) gives 2028 total admissions per 1000 "present." The admissions to the infirmaries in France (in 1866) were 323 per 1000 "present," to the hospitals, 306; making a total of the severer cases of only 629 per 1000 in that year. This shows how many slight cases there are in the French army. In the eight years 1862–69 the mean number of slight cases in France was 1745 per 1000. In the ten years 1873–82 the admissions to the infirmaries were 319; to the hospitals 264; and "*à la chambre*," 2009 (Morache).

In the Prussian army the average admissions (mean of 18 years, 1846–63) were 1336. In 1867 there were 1125·6 per 1000. In 1873–75 it was 750, and in 1876 only 620 (Roth).

(*b*) *Daily Number of Sick in Hospital per* 1000 *of Strength.*—About one-twenty-fifth of the army is constantly sick in time of peace, or 4 per cent. The mean for the ten years 1860–69 was 4·78 per cent. (or one-twenty-first part), and for the ten years 1870–79 it was 3·95 per cent., or just under one-twenty-fifth. In the ten years 1874–83 it was 4·28 per cent., or one-twenty-fourth; in 1884 it was 4·88, or just under one-twentieth.

It is not possible to compare the army sickness with the civil population, or even with other armies.

In England the number of members of friendly societies, between twenty and thirty years of age, who are constantly sick, is nearly 16 per 1000.

In the French army the mean sick in hospital are 29 per 1000 present; in both hospital and infirmary, 50; in the Prussian, 44 (in 1876 only 25·5); in the Austrian, 45; in the Belgian (1859), 54·2; in the Portuguese (1851–53), 39·4.

The number of daily sick has, of course, a wide range; sometimes an hospital is almost closed, at other times there may be more than 100 sick per 1000 of strength.

(*c*) *Number of Days spent in Hospital per head in each* 1000 *of Strength.*—The number of days' service of a battalion 1000 strong in a year would be of course ($1000 \times 365 =$) 365,000. If we assume the average number of sick to be $39\frac{1}{2}$ per 1000, there are lost to the State ($39\frac{1}{2} \times 365 =$) 14,417 days' service per annum, or $14\frac{1}{2}$ days per man. In 1874–83 the number of days' sickness per man at home was 15·62, in 1884 it was 17·87. As already said, it is difficult to compare the sickness of soldiers and civilians, but the above amount seems large when we remember that, in the friendly societies, the average sickness per man per annum (under forty years of age) is less than seven days.

Mean Duration of Cases of Illness.—The number of days each sick man is in hospital (mean duration of cases) is rather greater (18·59, average of 10 years 1874–83), as the number of admissions is below the strength. In 1884 it was 20·53.

It can be most easily calculated as follows:—multiply the mean daily number of sick (sick population) by the number of days in the period, and divide by the cases treated. The number of "cases treated" is the mean of the admissions and discharges in the period.

Austrian army, 17 to 18 days.
French at home, all cases (1862–66), 7·97 days.
French in hospitals only (1862–66), 26·3 days.
French in infirmary, 12 days.
French *à la chambre*, 3·10 days.
Prussian (1859–63) in hospitals, 18·9 days.
Belgian, 23·6 days.
Portuguese, 19 days.

(*d*) *Mortality to Sickness.*—This is, of course, a different point from that of the relation of mortality to strength. A few cases of very fatal illness may give a large mortality to cases of sickness, but the mortality to strength may be very small.

The mere statement of the ratio of mortality to sickness gives little information; what is wanted is the mortality of each disease, and at every age. Otherwise the introduction of a number of trifling cases of disease may completely mask the real facts.

When, however, the general ratio is to be determined, it must be calculated in one of three ways:—

1. Mortality to admissions in the time. This is, however, an uncertain plan; a number of cases admitted towards the close of a period, and the greater part of whose treatment and mortality falls into the next period, may cause an error.

2. Mortality to cases treated (= mean of admissions and discharges). This is the best method of calculation.

3. Mortality to sick population, *i.e.*, the number of deaths furnished per annum by a daily constant number of sick. This, however, must be taken in connection with the absolute number of sick in the time, and with the duration of the cases, or, in other words, with the kind of cases.

The degree of mortality to the several causes of sickness was given very fully in the statistical part of the *Army Medical Department Reports*, up to the year 1873, since which time the detailed returns have been discontinued.

Calculated on the admissions, the mortality to total sickness in the English army at home is a little above the mortality to strength, or about 9·5 per 1000 per annum (1874–83). In 1884 the ratio was 6·4. In the Prussian army it was 7·25 (years 1846–62); in 1872 it was 7·7.[1]

Causes of Sickness.

The causes leading men to go into hospital are, of course, very different from those which produce mortality. For example, admissions from phthisis will be few, mortality great; admissions from skin diseases numerous, mortality trifling.

Taking the most common causes of admission, we find—

1. *Venereal Diseases.*—Under the term venereal, all diseases, immediate or remote, resulting from sexual intercourse, are included. Secondary as well as primary syphilis; stricture and orchitis, as well as gonorrhœa, &c.; also a few cases not strictly venereal. The primary venereal forms are, however, of the most importance.

In stations under the Contagious Diseases Act, 1000 men gave 50 admissions from primary venereal sores and 84 from gonorrhœa (average of 13 years 1870–82). In stations not under the Act, the amounts were, respectively, 118 and 105. There were other admissions from secondary and tertiary syphilis, which somewhat increased the total admissions. In May 1883 the compulsory examination of women was discontinued, and the Contagious Diseases Acts repealed in the following year. The result has at once shown itself. In the stations formerly under the Acts the admissions for primary venereal sore at once rose in 1883 to 110, and in 1884 to 138; the number constantly sick being 8·66 and 12·41 per 1000 respectively, against 6·51 in 1882 and an average of 3·97 for the previous 13 years.

We have no certain facts with which we can compare the syphilitic disease

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[1] For numerous statistical details of foreign armies, see Roth and Lex, *op. cit.*, vol. iii. p. 411 *et seq.*

of the civil population with that of the army. The amount among the civil population at large is really a matter of conjecture. But whether it is greater or less than that of the army does not affect the result drawn from the above figures, viz., that there is an appalling loss of service every year from the immediate or remote effects of venereal disease,[1] a loss which unfortunately is likely to increase.

It should be understood, also, that the action of syphilis is long continued. Many soldiers die at Netley from various diseases, whose real affection has been syphilis, so that the influence of this cause is very imperfectly indicated by the number of admissions and the service lost under the head of syphilitic disease only.

2. *General Diseases.*—The important diseases included under this class give about one-fourth of the total admissions, or about 220 per 1000 (1879–1883).

(*a*) Eruptive fevers are not very common—about 5 per 1000. Smallpox is checked by vaccination; measles and scarlatina are not frequent.

(*b*) Paroxysmal fevers (most of which have been contracted out of England) give about 13 per 1000.

(*c*) The continued fevers are more common, but their frequency is lessening. There is no doubt that enteric fever is the chief, perhaps almost the only fever besides febricula which is now seen. The admissions for enteric fever alone in five years (1879–83) give a mean of 1·4 per 1000; in 1884 they were 1·1. Spotted typhus is at present uncommon, but does occasionally occur. The continued fevers cause about 15 admissions per 1000 of strength (1879–83). Of late years there have been some cases of cerebro-spinal meningitis.

(*d*) Rheumatism gives about 40 cases per 1000 of strength.

3. *Accidents* give the next greatest number; mean (1879-83) 106; range from 102 to 117 per 1000.

4. Diseases of the *Digestive* system follow, about 110; range from 102 to 116.

5. *Cutaneous* diseases give a mean of 111; range from 102 to 123.

6. *Respiratory* diseases (not including *Phthisis*) give a mean of 75 per 1000; range from 63 to 97.

7. Diseases of the *Eye*, mean 15, with little variation.

8. Diseases of the *Circulatory* system, 14.

9. *Phthisis* 10, with range between 8·5 and 11 (1884, 7·5).

10. *Nervous* system, 12, with a range between 11 and 13.

11. The remaining diseases of numerous smaller items, such as those of the *generative* (*venereal* excluded), *locomotive*, urinary (*gonorrhœa* excluded), &c.

As almost all details of these different groups are now omitted from the *Army Medical Reports*, it is difficult to discuss their causation and possible diminution.

There is no room for doubt that the venereal admissions could be greatly lessened but for the late action of the Legislature; so also could the admissions from fever, which have in fact been already reduced from 60 to 15 per 1000 of strength; in 1883 and 1884 they were only 13. For enteric fever they were only 1·4 and 1·1 respectively. The large class of integumentary diseases would probably admit of reduction. What is the exact nature of the phlegmon and ulcers which form so large a proportion of the admissions? Trifling as the cases are, they form a large aggregate, and a careful study of their mode of production might show how they might be diminished. Pro-

[1] The order issued in 1873, directing stoppages to be made from men in hospital affected with venereal disease, was a most unfortunate one, as giving every inducement for the concealment of disease. Happily it was rescinded in 1879.

bably, however, these are mere conventional terms, under which a number of trifling cases are conveniently recorded, but a complete analysis of the returns of one year under phlegmon would be desirable. So also of all the other classes, it may be concluded that an active medical officer might succeed in reducing the cases of rheumatism, bronchitis, and dyspepsia.[1] Many cases of acute respiratory diseases are produced by exposure on guard, especially by the passage into and from the hot close air of the guard-room to the open air on sentry duty. Good additional overcoats, means of drying the clothes, and proper ventilation of the guard-rooms, would probably lessen the cases of bronchitis and pleurisy.

Sickness in Military Prisons.—The admissions into hospital in the military prisons do not appear to be great; they have varied per 1000 of admissions of prisoners from 316 (in 1851) to 725·5 in 1863.[2] Calculated on the mean strength, the result is as follows:—In 1863 the daily average number of prisoners was 1064; the admissions for sickness, 722; the mean daily sick, 21; the mortality, 0. These numbers give 725·5 admissions, and 19·74 mean daily sick per 1000 of strength. Prisoners are healthier than their comrades at duty in the same garrisons where the prisoners are under sentence.

SECTION IV.

Soldierly Qualities.

Such, then, being the amount of mortality and sickness at home, it may be concluded that the soldier at present is not yet in so good a condition of physical health as he might be; and we can confidently look to future years as likely to show a continuance in the improvement now going on. In future years, however, the new system of limited service will render it difficult to trace the progress in the infantry.

Health is so inextricably blended with all actions of the body and mind, that the medical officers must consider not only all physical but all mental and moral causes acting on the men under their charge.

The amount of work, the time it occupies, its relation to the quantity of food, the degree of exhaustion it produces, the number of nights in bed, and other points of the like kind; the mental influences interesting the soldier, or depressing him from *ennui*; the moral effect of cheerfulness, hope, discontent, and despondency upon his health, as well as the supply of water, air, food, clothing, &c., must be taken into account. And just as the body is ministered to in all these ways, so should there be ministration of the mind. It is but a partial view which looks only to the body in seeking to improve health; the moral conditions are not less important; without contentment, satisfaction, cheerfulness, and hope, there is no health.

Hygiene, indeed, should aim at something more than bodily health, and should indicate how the mental and moral qualities, essential to the particular calling of the man, can be best developed.

How is a soldier to be made not merely healthy and vigorous, but courageous, hopeful, and enduring? How, in fact, can we best cultivate those martial qualities which fit him to endure the hardships, vicissitudes, and dangers of a career so chequered and perilous?

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[1] It is right, however, to say that no medical officer ought to sacrifice his men in the slightest degree for the purpose of appearing to have a small sick list and an empty hospital. There is a temptation in that direction which we have to guard against, and to remember that the only question to be asked is, What is the best for the men? not, What will make the best appearance?

[2] *Report on Prisons* for 1863, p. 24.

Without attempting to analyse the complex quality called courage,—a quality arising from a sense of duty, or love of emulation, or fear of shame, or from physical hardihood, springing from familiarity with and contempt of danger,—it may well be believed that it is capable of being lessened or increased. In modern armies, there is not only little attempt to cultivate courage and self-reliance, but the custom of acting together in masses and of dependence on others actually lessens this. It is, then, a problem of great interest to the soldier to know what mental, moral, and physical means must be used to strengthen the martial qualities of boldness and fortitude.

The English army has never been accused of want of courage, and the idea of pusillanimity would seem impossible to the race. But drunkenness and debauchery strike at the very roots of courage; and no army ever showed the highest amount of martial qualities when it permitted these two vices to prevail.[1] In the army of Marlborough, the best-governed army we ever had, and the most uniformly successful, we are told that the "sot and the drunkard were the objects of scorn." To make an army perfectly brave, it must be made temperate and chaste.

Good health and physical strength, by increasing self-confidence, increase courage; and self-reliance is the consequence of feeling that, under all circumstances, we can face the dangers and difficulties that present themselves.

Few wiser words were ever written than those by William Fergusson,[2] at the close of his long and eventful service.

"Of the soldier's life within these barracks," writes Fergusson, "there is much to be said, and much to be amended. To take his guards, to cleanse his arms, and attend parade, seems to comprehend the sum total of his existence; amusement, instruction beyond the drill, military labour, and extension of exercises, would appear, until very recently, to be unthought of; as it is impossible that the above duties can fully occupy his time, the irksomeness of idleness, that most intolerable of all miseries, must soon overtake him, and he will be driven to the canteen or the gin-shop for relief.

"Labour in every shape seems to have been strictly interdicted to the soldier, as water for his drink. All, or nearly all, must have been bred to some trade or other before they became soldiers; but they are work for them no longer. Labour (the labour of field-works and fortifications) strengthens the limbs and hardens the constitution, but that is never thought of in our military life at home; so thought not the ancient Romans, whose military highways still exist, and who never permitted their soldiers to grow enervated in idleness during peace. Better, surely, would it be that every one should work at his own craft, or be employed on the public works, in regulated wholesome labour, than thus to spend his time in sloth and drunkenness. But his exercises, without even going beyond the barrack premises, may be made manifold—running, wrestling, gymnastic games of every kind, swimming, leaping, pitching the bar, the sword exercise (that of the artillery), all that hardens the muscles and strengthens the limbs, should be encouraged; and, when the weather forbids out-door pastimes, the healthy exercise of single-stick, in giving balance and power to the

[1] There are many sober and excellent men in the army. But as a rule the English soldier cannot be depended upon under any circumstances if he can get drink. Well does Sir Ranald Martin say, "Before that terrible vice can be overcome, something far more powerful than medical reasoning on facts, or the warnings of experience founded on them, must be brought into active operation. Discipline must still further alter its direction: in place of being active only to punish wrong, it ought and must be exerted further and further in the encouragement to good conduct."—Ranald Martin, *Tropical Climates*, p. 263.

[2] *Notes and Recollections of Professional Life*, 1846, p. 49.

body, quickness to the eye, and vigour to the arm, may properly be taken as a substitute for the drill which, after the soldier has been perfected in his exercise, is always felt to be a punishment. So is the unmeaning evening parade and perpetual roll-calling.

"Foot-racing too, the art of running, so little practised, and so supremely useful, should be held amongst the qualities that constitute military excellence. It was so held at the Isthmian games of ancient Greece, and deserves a better place than has hitherto been assigned to it in the military pastimes of modern Britain. In our school-books we are told that the youth of ancient Persia were taught to launch the javelin, to ride the war-horse, and to speak the truth. Let the young British warrior be taught to use his limbs, to fire ball-cartridge, to cook his provisions, and to *drink water.* The tuition may be less classical, but it will stand him in far better stead during every service, whether at home or abroad.

"Regular bodily pleasurable exercise has been said to be worth a host of physicians for preserving military health; and occupation without distress or fatigue is happiness. The philosopher can make no more of it; and every idle hour is an hour of irksomeness, and every idle man is, and must be, a vicious man, and to a certain extent an unhealthy one."

In many of the foreign stations of the British army, excellent opportunities exist for both occupying the men and developing their spirit. All history teaches us that a hunting race is a martial one. The remarkable fighting qualities of the English, as drawn in Froissart's *Chronicles*, were owing to the fact that at that time they were "a nation of hunters," and trained from infancy to face dangers alone. In India there are many places where men could not only be allowed to hunt, but where such permission would be the greatest boon to the inhabitants.

The English army has hitherto offered but few incentives to good conduct, and scanty encouragement for the cultivation of martial qualities. Men must have rewards, and feel that earnest endeavour on their part to become in all respects better soldiers is neither overlooked nor unrewarded. The new order of things introduced by the late Lord Cardwell seems likely to open up means of progress for men who can acquire knowledge and to deserve advancement.

The cultivation of the martial qualities of the soldier is in reality a part of hygiene considered in its largest sense, but this part of hygiene must be studied and carried into effect by the combatant officers. Let us trust it may not be long before they seriously study and endeavour, by precept and example, to promote the formation of those habits of boldness and endurance, and that fertility in resources, which are as necessary as technical knowledge to render an army the formidable instrument it is capable of becoming.

CHAPTER IV.

FOREIGN SERVICE.

The foreign service of the British army is performed in every part of the world, and in almost every latitude, and probably more than two-thirds of each line soldier's service is passed abroad. The mere enumeration of the stations is a long task; the description of them would demand a large volume. In this short chapter, to give a few general statements as to climate and geology, and the past and present medical history of the stations, only can be attempted; such an outline as may give medical officers a sort of brief summary of what seems most important to be known.

Detailed and excellent accounts of most of the foreign stations exist, either in the independent works of army surgeons, such as those of Marshall, Hennen, Davy, and many others, or in reports drawn up for Government, and published by them. In the early *Statistical Reports of the Medical Department of the Army*, short topographical notices of the stations were inserted; they are models of what such reports should be, and must have been drawn up by a master in the art of condensation. In the *Annual Reports* now published many excellent topographical descriptions will be found; and some of the Indian Governments have published complete descriptions of all their stations. In the *Bombay Transactions*, the *Madras Medical Journal*, and the *Bengal Indian Annals* are very full accounts of almost every station that has been or is occupied by European troops in India. Finally, in the *Indian Sanitary Report* is much important information on the meteorology and topography of the present Indian stations. Young medical officers first entering on foreign service are strongly advised to study these accounts of the stations in the command where they are serving; it will not only give them interest in their service, but will aid them in their search how best to meet the climatic or sanitary conditions which affect the health of the men under their charge.

SECTION I.

MEDITERRANEAN STATIONS.[1]

Gibraltar.

Usual peace garrison = 4500 to 6000 men. Period of service, three years. Civil population = 18,381 (in 1881). Height of rock, 1439 feet at highest point. Nature of rock, grey limestone, with many cavities filled with reddish clay; under town, an absorbent red earth forms the subsoil.

Climate.—Mean temperature of year = $64^\circ\cdot1$;[2] hottest month, August

[1] A very important Report on the Mediterranean Stations was published by the Barrack Improvement Commissioners (Dr Sutherland and Captain, now Sir Douglas, Galton).—*Blue Book*, 1863.

[2] Mean of eight years' observations by the Royal Engineers (1853-60), as given in the *Barrack Commissioners' Blue Book* (1863).

(invariably in eight years) = 76°·6; coldest month, either January or February, in equal proportions, 53°·77: amplitude of the yearly fluctuation, 22°·83 (= difference between hottest and coldest months).

Mean monthly maximum and minimum in shade[1]—hottest month, July or August—mean maximum = 89°; coldest month, December, January, or February—mean minimum, 42°. Range of highest and lowest monthly means of maximum and minimum, 47°. Extreme yearly range (difference between highest and lowest temperature recorded in the time) about 50° to 58°. The minimum thermometer on grass sometimes falls to 4° or 6° below freezing.

Rainfall.—Mean, 32·8 inches (mean of seventy years, 1790–1860). Greatest amount in any one year, 75·8 (1855). Least amount in any one year, 15·1 (1800). The importance of this great variation, as regards sieges, is evident; Gibraltar might be embarrassed for water if the rainfall were only 15 inches in a year of siege.

Number of Rainy Days = 68. The rain is therefore infrequent, but heavy. The rain falls in nine months, September to May; greatest amount in January and November; most rainy days in April. Summer, rainless.

Humidity.

	Dew-point.	Grains of Vapour in a cubic foot.	Relative Humidity Sat. = 100.
Mean dew-point of year,	55°·9	5·75	72·3
Mean highest dew-point in August, . .	67°·9	7·50	70·7
Lowest dew-point in January or February, . .	43°·5	3·25	69·1

Gibraltar is thus seen to be rather a dry climate; at any rate, the air is on an average only three parts saturated with moisture, and therefore evaporation from the skin and lungs will be tolerably rapid, provided the wind moves freely. It is certainly not a moist insular climate, as might have been anticipated. At the times of rain, however, and during the fogs and moist sirocco, the air is nearly saturated.

Winds.—Chiefly N.W. or S.W. or W., in January, April, May, June, and October. Easterly in July, August, and September. But sometimes the easterly winds are more prevalent, or may be moderate for almost the whole year. The east and south-east winds are sirocco (Levanteros), and are often accompanied by rain and fogs.

Sanitary Conditions.

Water Supply.—The *quantity* was formerly very deficient; in 1861 only $2\frac{1}{2}$ gallons daily were supplied for non-commissioned officers and privates.

Sources.—Wells and tanks, rain-water, and a small aqueduct carrying surface water. Very large tanks have been constructed in two of the ravines, with arrangements for passing into them a large amount of surface water;

[1] Of the eight years (1853–60) given in the report above quoted, the difference between the monthly mean maximum and minimum is so much less in the last three years as to make one suspect some error in observation. In 1880 the mean maximum in July was 87°·4, the mean minimum in January 47°·9—range 39°·5; absolute maximum 98°·8 in August, absolute minimum 42°·5 in January—range 49°·3.

and fresh wells have been dug at the north end, near the neutral ground, which yield a large supply of water.

Quality.—The most of the well water is very hard, and in some cases almost brackish. In one sample analysed at Netley there were nearly 83 grains of chlorine per gallon, equal to nearly 140 grains of alkaline chlorides. Some of the wells contain a good deal of organic matter, whilst others are comparatively free. In most of them there is a large quantity of nitrates, pointing unequivocally to the oxidation of animal organic matter. Recent experimental borings have not been very encouraging as regards quality of water.[1] The tank water is good when filtered; but the tanks require frequent inspection and cleaning.

Many of the houses of the civilians have tanks, and no new house is allowed to be built without a tank. The distribution of water, both to soldiers and civilians, is defective; it is almost entirely by hand.

Drainage.—The sewers have been much improved. Surgeon-General A H. Fraser reported in 1884 that "the drainage and general sanitary condition was satisfactory on the whole."

Barracks.—More than half the garrison is in casemates, which have been described as "mere receptacles of foul air, damp, dark, and unwholesome."[2] The barracks are, for the most part, badly arranged, and are overcrowded; the average cubic space in 1862 was only about 450 feet, and the average superficial space under 40. Ventilation was very defective, especially in the casemates. The means of ablution and the latrines and urinals were also defective. In all those points, however, great improvement has taken place. The duties are not heavy, and the rations are said to be good. In 1860 some improvements were made in the dress of the troops, and a light summer suit ordered. Flannel next the skin has been recommended strongly for Gibraltar, on account of the occasional cold winds.

Health of the Civil Population.

Gibraltar is now a place of considerable trade; whether the Government have been right in allowing a mass of people to herd closely together in the midst of the most important fortress we possess is very questionable. In case of a siege they would be a serious embarrassment, and even in time of peace they are objectionable. The health of this community is bad; in 1860 the northern district, where population is densest, gave 38 deaths per 1000, or excluding cholera, 33·5; in the more thinly populated southern end, the mortality was 27·5 per 1000, or more than St Giles', in London. The deaths in children under one year form 17·33 per cent. of the total mortality. The prevailing causes of this mortality are fevers (in all probability typhoid) and tuberculous consumption, which causes 13 per cent. of the total deaths at all ages, or 37·6 per cent. of the total deaths at the soldiers' ages. Dysentery and diarrhœa are common.

In this compressed and dirty population several great epidemics have occurred. The bubo plague does not appear to have been seen since 1649, but the earlier records are very imperfect; yellow fever, however, prevailed in 1804, 1810, 1813, and 1828. Cholera has prevailed several times; the last time was in 1865.

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[1] For analyses of water of Gibraltar, see Reports on Hygiene, *Army Medical Reports*, vols. xviii., xix., xx., and xxi.

[2] *Barrack Commissioners' Report*, p. 37.

HEALTH OF THE TROOPS.

1. *Loss of Strength by Death and Invaliding.*

(*a*) *By Death.*—Gibraltar has never suffered from any great sickness or mortality, except in yellow fever or cholera years. At the time when the mortality on home service was 17 or 18 per 1000 of strength, it was usually not more than 12 at Gibraltar. Of late years both sickness and mortality have been below that of home service, especially in the latter years. In spite of this comparative healthiness, it is quite certain that much preventible disease existed, and in part still exists, on the Rock.

Mortality per 1000 *of Strength.*

Years.	Total Deaths.	Deaths from Disease alone.
1837–46 (10 years),	12·9	5·65
1861–70 (10 years),[1]	8·54	
1870–79 (10 years),	6·98	
1879–63 (5 years),	6·94	6·11
1884,	4·03	3·61

The progressive diminution is remarkable, and shows what is possible in reducing mortality among soldiers.

Causes of Death.—In the earlier years the chief causes of death were phthisis and continued fever, which was doubtless enteric fever. Of late years phthisis has declined; enteric fever, on the contrary, increased up to 1863, has since then declined in frequency, though not in fatality per cent. of attacked.

The admissions from phthisis averaged 11 per 1000 of strength in the ten years 1836–48; while in the eight years 1859–66 they were only 7·63. In the years 1863–66 the deaths and invaliding together from phthisis were only 3·72 per 1000 of strength, or hardly more than the deaths alone at home. In 1879–83 the admissions were 4·8; deaths 1·01; invalided, 2·07. In 1884 the admissions were 5·5, the deaths 0·85, and the invaliding 0·85. The two last together make 1·75, against 4·52 at home. The decline in phthisis seems therefore certain, but still it is possible that it is not even now so low as it might be.

The continued fevers gave 75·7 admissions per 1000 of strength in the years 1837–46, and 98·5 in the five years ending 1863. There was also an increase in mortality. In the three years ending 1866 the admissions fell to an average of 42, and the decline was progressive. Of late the admissions have increased, the numbers for 1869–78 being 77 per 1000, in 1879–83 nearly 153, in 1884 no less than 176, but of these last only 0·6 were enteric, the remainder being febricula and so-called Rock-fever.

During late years much has been done in Gibraltar to give the men more breathing space and ventilation, hence the decline in phthisis which was so fatal formerly when the men were crowded in casemates. When their barracks are still further improved, we shall see a still greater lessening of phthisis.

The amount of heart disease was formerly great, and probably arose from the same conditions as at home. It has latterly diminished considerably.

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[1] Cholera prevailed in 1865, and raised the mortality to 23·74. Without cholera it was 7·91.

[2] Of course invaliding has an effect, but the invalids who died at Netley are included in the above numbers.

The habits of the men are much improved, and *delirium tremens*, formerly common, is rare. In 1865 and 1866 only one man died in two years from this cause, or at the rate of scarcely more than 0·1 per 1000 of strength.

Formerly dysentery and diarrhœa were common; now they are infrequent and mild. The average admissions from dysentery in three years (1864–66) were only 2 per 1000; in 1864 and 1866, from diarrhœa, were only 12 per 1000.[1] In 1880 they were under 11. In 1884 the cases were much more numerous. Coincident with the presence of cholera in Europe there was, however, no actual cholera reported.

Everything points to the fact that Gibraltar itself is a perfectly healthy place, and that, when the sanitary alterations now going on are completed, the sickness and mortality will be trifling.

Influence of Age on Mortality at Gibraltar.

Years.	Deaths per 1000 of Strength at each Period.					
	Under 20.	20 and under 25.	25 and under 30.	30 and under 35.	35 and under 40.	40 and upwards.
1874–83	3·83	5·08	5·14	7·12	7·92	18·04
1884	5·05	2·09	4·20	5·17	4·31	...

These numbers compare favourably with the home returns.

(*b*) *By Invaliding.*—The number of men sent home for change of air and discharge varies greatly from year to year; about 20 to 30 per 1000 of strength is the average. The chief diseases are general debility, rheumatism, phthisis, and cardiac disease. The other diseases are in smaller number, but are numerous. Dysentery and liver diseases used to be common causes of invaliding, but both are now declining. The total number was 33·10 per 1000 in 1884, of whom only 9·76 were finally discharged.

2. *Loss of Service by Sickness.*

The admissions, the mean daily sick, and the duration of the cases, are all below the home standard.

Per 1000 *of Strength.*

Years.	Admissions per Annum.	Mean daily Sick.	Mean Stay in Hospital of each Sick Man in Days.
1837–56,	976	...	...
1861–70,	742	36·57	18·39
1870–79,	669·4	35·88	19·62
1879–83,	831·1	51·98	22·83
1884,	966·9	55·65	21·06

The venereal diseases cause a good many admissions. There is police regulation of prostitutes, but it is imperfectly carried out. Integumentary diseases cause about 43 admissions per 1000. In 1884 these amounted to 56. Digestive disorders give a large number of admissions, and have always done so, but in the latest returns they are somewhat declining.

[1] Cholera prevailed in 1865, so that year has been left out.

Sanitary Duties at Gibraltar.—Sir Douglas Galton and Dr Sutherland indicated the measures which should be adopted, viz., a better supply of water by arranging for a larger storage; a better drainage, with sea water for flushing, and a different outlet; and an improved ventilation, with less crowding in barracks. Most of the plans have been carried out as far as practicable. There is no doubt these measures will greatly improve health.

Supposing war were to arise at this moment, and that we lose the command of the sea for a time, the points of danger would apparently be these:—

1. *Deficient Water, the Rainfall being uncertain.*—The new wells near the neutral ground will perhaps obviate this danger, but the water is not of good quality; but if not, it would have to be supplied by distillation, and it would be prudent to keep a good apparatus always at Gibraltar. The amount of storage has been increased of late years.

2. *Overcrowding and Bad Ventilation, leading to Spotted Typhus.*—With a full garrison, and with some barracks untenable, there is no doubt there would be serious danger of this disease; and it is a matter of great moment to ventilate as perfectly as possible all casemates which, even if now disused, must be used in time of war.

3. *Enteric Fever.*—By means of improved drainage this cause of danger might soon be entirely removed.

4. *Diseases arising in the Town, and spreading to the Garrison.*—In case of war, it would seem most desirable to clear out the native town as far as it can be done. More space and more water would be available. There would be less chance of famine, destitution, and disease.

In the war in 1792 scurvy prevailed from deficiency of food and fresh vegetables.

MALTA.

Size, 17 miles by 9. Usual peace garrison = 5000 to 7000; period of service, three years; population (civil) in 1879 = 154,198.

Geology.—Soft, porous rock; the greater part is sandstone resting on hard limestone; in some parts there is marl and coral limestone over the sandstone. In the centre of the island, at Citta-Vecchia, there is, in order from the surface, alluvium, upper limestone, red sand, marl, sandstone, and lower limestone. Valetta is on thin alluvium, with thick sandstone below, and beneath this the lower limestone.

Climate (at Valetta).—Mean of the year,[1] 66°·8; hottest month (July), 77°; coldest (January), 57°; amplitude of the yearly fluctuation, 20°; extreme yearly range (from highest to lowest temperature in shade), 59°, from 99° in July to 40° in January; mean yearly range, about 53°.

Undulations of temperature are frequent, and there are often cold winds in winter from N.W. The south-east wind is an oppressive sirocco, raising the temperature to 94° or 95°. It is chiefly in the autumn, and blows for from 60 to 80 days every year. At Citta-Vecchia (600 feet above the sea) the temperature is lower and the air keener. Rainfall about 22 inches. Chief rain in November, December, and January; less in February and March; small in amount in the other months. From June to August almost rainless.

Humidity.—Mean of 1869–80; observations at 9.30 A.M. Relative humidity, 70.

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[1] For eleven years (1869–80), with the exception of 1874, not recorded in *A.M.D. Reports.*

Malta thus appears to be a dry climate, *i.e.*, with a moderate relative humidity.

Sanitary Condition.

Much has been done of late years, and, as far as external cleanliness goes, Valetta is very clean. Water supply from rain and springs (the largest of which is in the centre of the island, and the waters of which are led by aqueduct), is not very deficient in quantity (8 to 10 gallons per head), and, except in some places, good in quality, though the rain-water contains chlorides from the spray falling on the roofs of buildings. Some of the tanks are too near the sea, which percolates into them. The tanks require careful looking after. Within the lines there are 272 public and military tanks, with storage for 55 millions of gallons, and 4294 private tanks, with storage for 323 millions of gallons. The military tanks, if full, would give 6 gallons of water per man daily for eleven months, but even now the water often falls short. The water is carried everywhere by hand, and the drinking water for the men is not filtered, or only partially so. An attempt to get water by sinking into the sandstone was made in 1866–67, but failed. The sewers in Valetta are bad in construction and outlet, and much enteric fever has been, and is still, caused in consequence. In many cases "they are nothing but long cesspools."[1] Pipe drains are, however, now being laid in the old drains, which were merely narrow deep channels cut in the soft porous rock. The old style of drain has now quite ceased to exist in the barracks.

The barracks are bad, many casemates being used, and buildings which were intended for stores and not for habitations. They are built of soft sandstone, which both crumbles and absorbs wet. In some cases all sanitary considerations have been sacrificed for the purposes of defence. The ventilation of the casemates is very bad, but some improvements have taken place. The Barrack Commissioners, in their *Report*, recommended that in every way which could be done the ventilation should be improved by admitting the wind, especially from the north, and that each barrack would require a separate plan to meet the particular case. They recommended that air shafts should be made, much larger than ordered for home service, viz., 1 square inch for every 20 cubic feet of space, or for a barrack-room of twelve men with regulation space ($7200 \div 20 =$) 360 square inches ($= 2\frac{1}{2}$ square feet) of outlet opening. Some of those points have been carried out with very good results. At the present time the amount of cubic space is below the home-service amount (600 cubic feet), and the superficial area is very small, in some cases being as low as 40 square feet per head. All the barracks are now supplied with new and remodelled married quarters, with proper appliances.

During the hot weather the space is increased by making the men sleep under canvas every alternate night.[2]

A gymnasium is provided both in Cottonera and Valetta, and all the barracks are well provided with reading, recreation, and school rooms. The means of ablution are now very good in all the barracks, and there are new water latrines and slate or earthenware urinals provided.

We may therefore hope that a diminished amount of disease may be the result of these improvements, although much remains to be done to make the condition of the troops as good as it ought to be.

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[1] *Barrack Commissioners' Report*, p. 111.

[2] Report by Surgeon-General W. A. Mackinnon, C.B., *A.M.D. Reports*, vol. xxii. p. 235.

Health of the Civil Population.

There is some, but no great amount, of malarious disease, but a good deal of the so-called bilious remittent[1] and enteric fever. Typhus is not at present seen. Bubo plague has prevailed seven times, the last in 1841, slightly. Yellow fever has been known, but not of late years. Cholera has occurred thriee. Dysentery is common; tænia not infrequent; ophthalmia common, from dust and glare. Boils or anthrax are frequent; rheumatism is not uncommon, and phthisis is said to be frequent (from dust?). The death-rate is said to be 21·3 per 1000 in the towns, and 28·7 in the country districts; while nearly 57½ per cent. of this is in children under five years,[2] the great causes of infantile mortality being registered as teething and convulsions.

Health of the Troops.

The health of the troops is worse than at Gibraltar, but it has singularly fluctuated (even without great epidemics), more so probably than at any station in the same latitude. The mortality has varied as much as threefold without cholera.

Years.	Loss of Strength per 1000 per annum.			Loss of Service per 1000 per annum.		
	Total Deaths.	Deaths from Disease.	Invaliding.	Admissions.	Mean daily Sick.	Days in Hospital to each Sick Man.
1837–46, . . .	15·3	...	...	1120	43·79	...
1861–70 (10 years), .	13·49	...	22·2	798·6	43·31	19·81
1870–79 (10 years), .	9·77	...	30·00	837·8	42·35	18·45
1879–83 (5 years), .	9·47	8·01	12·60	840·7	51·29	22·28
1884, ...	9·27	7·76	17·89	840·4	55·84	24·24
Highest (1865, cholera),	26·44	24·63	...	...	...	...
Lowest (1864), . .	6·53	4·58	...	...	...	...

The mortality in 1864 was as low as it has ever been; but it has in former years been as low as 5·6 from disease alone. It is curious how alternations of health and sickness occur chiefly from the variations in the fevers of different kinds, especially enteric and the remittent or so-called Malta fever, which has a long course, a great tendency to rheumatic sequel, and little mortality.

In 1867 there was a terrible outbreak of continued fever, chiefly among the troops quartered in the notoriously unhealthy barracks of Lower St Elmo and Fort Ricasoli. The admissions rose to 228, and the deaths actually amounted to no less than 7·93 per 1000 of strength. Out of 100 deaths no less than 32·2, or nearly one-third, were from "continued fever," *i.e.*, enteric fever in great measure. In 1872 there was also a great deal of fever, the admissions being 233, and the deaths 3·91, per 1000 of strength. In 1878, also, there were 209 admissions and 5·16 deaths per 1000 of strength, the

[1] See Dr Marston's excellent Report in the *Army Medical Report* for 1861, for the symptoms of this disease among troops. See also Dr Boileau's interesting essay in the same publication, vol. viii.

[2] *Report of Barrack Commissioners*, p. 87. The Commissioners justly remark that these figures are so striking as to demand further inquiry. Probably they are quite untrustworthy: yet both at Gibraltar and Malta it would be of the greatest importance not merely for the health of the troops in peace, but for the security of the fortress in war, to know everything about the social life and the diseases of the native population.

deaths being in almost all cases enteric. In 1884 the deaths from enteric fever alone were 4·74 per 1000 of strength, and 51 per cent. of the total deaths, more than four times the home rates.

In former years phthisis was the cause of 39 per cent. of the deaths, or nearly the same as at Gibraltar. Latterly there have been fewer deaths at Malta, but a considerable number of tubercular cases are sent home. The disease is probably detected earlier, and the men do not die as formerly at the station. Still this does not account for the whole diminution, and there has been clearly a lessening of phthisis. There was formerly a large amount of stomach and bowel disease, and dysentery was forty times as frequent as in England.[1] It is certainly a very remarkable circumstance that both at Gibraltar and Malta there should have been this extraordinary liability to affections of the alimentary canal. At Malta, as at Gibraltar, it may have been chiefly owing to impure water and to food.[2] Of late years stomach and bowel affections have been much less frequent. In the three years 1878–80 the admissions at Malta were only 4·4, and in 1880 only 2·2 per 1000 and no deaths.

In the *Statistical Report* for 1853 it is observed that the number of cases of liver disease at Malta is remarkably high; and the writers, while believing there must be "something in the climate of Malta peculiarly favourable to the production of hepatic affections," were unable to find, on bringing the cases into relation with the temperature, any connection. The cause of this may be something very different, and it is very desirable that the food should be looked to.

The history of admission for venereal disease is important; in 1837–46, inclusive, the admissions were only 99 per 1000, or two-thirds less than at home; in 1859, when the next report appeared, they were 149 per 1000; and in 1860 they were 147·9 per 1000. In the early period there were police regulations, which were suspended in the two latter years. In June 1861 the police regulations were re-enforced, and the admissions for the year sank to 102. The 4th battalion of the Rifle Brigade showed the following remarkable result:—In the first half of 1861 there were 57 admissions; in the last half only 17. In 1862 the total number of cases of "enthetic disease" in the whole garrison was only 49·5; in 1863, 44·1; and in 1864, 53·2 per 1000. They were increased in that year by the women who came from Ionia with the troops. In 1865 they were 44; in 1866, 59·6 per 1000. In 1870 and 1871 the admissions were very few; in the latter year, which was the worst, the admissions of primary syphilis were only 8·3 per 1000 of strength. If the home return is looked at, it will be seen what an effect has been produced at Malta by good regulations, although the number of cases fluctuates from causes traceable to special influences; the reduction is almost entirely of syphilis, not of gonorrhœa. In the later years there has been an increase and considerable fluctuations. Such, then, in brief, seem to be the chief medical points of importance at Malta, viz., a liability to phthisis, less marked of late years; a great amount of fever, from bad sanitary conditions in great part; a liability to stomach and intestinal affections, which, though less obvious, is still great; and a singular tendency to a liver affection, which may be parasitic. The chief improvements advised by the Barrack Commissioners refer to a larger water supply, a better distribution, improved drainage, and efficient ventilation.

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[1] In England, in 1837–46, every 1130 men gave one case of dysentery; in Malta, in the same years, every twenty-eight men gave one case of dysentery. The mortality of the disease was, however, nearly the same (see pages 21 and 118 of the *Report* of 1853).

[2] *Report* of 1853, p. 118.

In the time of war, the dangers at Malta would be the same as at Gibraltar; the aqueducts might be cut by a besieging force, and the water supply restricted to the tanks.[1] Although these are supposed to hold a large quantity, they are not kept full, and could not, perhaps, be rapidly filled. The garrison might be driven to distil the sea water. A still more serious danger would be the overcrowding of a war garrison. Doubtless, in case of a war, the garrison would only be concentrated in the lines when the siege commenced. But the crowding during a siege of three or six months might be very disastrous. The danger should be provided for beforehand by a clear recognition of what accommodation would be granted for war, and how it is to be obtained without violating either the conditions of health or of defence.

On the Influence of Age on Mortality in Malta.

	Deaths per 1000 of Strength at each Period.					
	Under 20.	20 and under 25.	25 and under 30.	30 and under 35.	35 and under 40.	40 and upwards.
1874–83 (10 years),	4·90	9·48	7·08	8·89	12·45	12·09
1884, .	8·85	6·99	10·21	5·58	23·53	...

CYPRUS.

This station was first occupied in 1878. It is an island in the Levant, about 50 miles from the nearest mainland, and 240 from Port Said at the entrance of the Suez Canal. Size, 90 miles by 40; area about 4000 square miles; civil population about 185,000 (in 1881). Our information about the climate is as yet imperfect, but it appears to resemble that of Malta, with greater rainfall.

The stations at present occupied are Nicosia (592 feet above the sea), as headquarters; Polymedia camp (400 feet), by the bulk of the troops, from October to May; and Mount Troados (5720 feet), from May to October. The average strength (1880) was 443 officers and men. The mean temperature at Polymedia during the cooler season (November to May inclusive) is about 59° to 60°, of Mount Troados (May to September inclusive) about 64° Fahr. The rainfall appears to be considerable, for in seven months (November to May) in 1880 31·81 inches fell, of which no less than 12·26 were recorded in December alone. The number of rainy days in the seven months was 58. The prevailing wind would appear to be N.W.

On the first occupation in 1878 there was a great amount of sickness, chiefly from paroxysmal fever. This appeared to arise from the unsuitable sites selected for the temporary camps and the turning up of soil infiltrated with organic matter. During the five months (24th July to 31st December 1878) there were, out of a strength of 894 non-commissioned officers and men, 3931 admissions for disease and 36 deaths, or at the rates of 4397 and 40·3 per 1000 respectively. Expanding these to an annual rate, they amount to 10,094 admissions and 92 deaths per 1000 of strength, an enormous amount. 84 per cent. of the admissions and 61 per cent. of the deaths were due to fever, almost all paroxysmal (so-called remittent), only

[1] Dr Notter analysed, in 1872, fourteen of the tank waters of the different forts, and found the condition of the water to be satisfactory.

14 admissions (actual number) and 2 deaths being due to enteric. In 1879 (strength 660) there was a great improvement,—the ratios being 1470 admissions and 21 deaths per 1000, 35 per cent. of the admissions and 50 per cent. of the deaths being still due to paroxysmal fever. There were 3 deaths from dysentery, against 4 in 1878. In 1880 (strength 443) the total admissions were 1002·2 and the deaths only 2·26 per 1000 strength. Paroxysmal fevers gave only 196·4 of admissions and no deaths. The only death in the command was from pulmonary extravasation, and occurred out of hospital. In five years (1879–83) the total admissions were 972·4 per 1000, of which 866·3 were for disease; deaths (total 9·96) from disease alone, 7·66; invaliding (total 22·98) for discharge, 17·24; average strength, 495 men.

The possibility of placing the troops in the hills at a considerable elevation (Mount Troados, 5720 feet), during the hottest months, will always be a great advantage to this station.

SECTION II.

WEST INDIES.

The history of sanitary science affords many striking instances of the removal of disease to an extent almost incredible, but no instance is more wonderful than that of the West Indies. Formerly service in the West Indies was looked on as almost certain death. It is little over sixty years since the usual time for the disappearance of a regiment 1000 strong was five years. Occasionally in a single year a regiment would lose 300 men, and there occurred from time to time epochs of such fatality that it was a common opinion that some wonderful morbid power, returning in cycles of years—some wave of poison—swept over the devoted islands, as sudden, as unlooked-for, and as destructive, as the hurricanes which so sorely plague the

"Golden isles set in the silver sea."

What gave countenance to this hypothesis was, that sometimes for months, or even for a year together, there would be a period of health so great that a regiment would hardly lose a man. But another fact less noticed was not so consistent with the favourite view. In the very worst years there were some stations where the sickness was trifling; while, more wonderful still, in the worst stations, and in the worst years, there were instances of regiments remaining comparatively healthy, while their neighbours were literally decimated. And there occurred also instances of the soldiers dying by scores, while the health of the civil inhabitants in the immediate vicinity remained as usual.

If anything more were wanted to show the notion of an epidemic cycle to be a mere hypothesis, the recent medical history of the West Indies would prove it. At present this dreaded service has almost lost its terrors. There still occur local attacks of yellow fever, which may cause a great mortality; but for these local causes can be found; and otherwise the stations in the West Indies can now show a degree of salubrity almost equalling, in some cases surpassing, that of the home service.

The causes of the production, and the reasons of the cessation, of this great mortality are found to be most simple. It is precisely the same lesson which we should grow weary of learning if it were not so vital to us. The simplest conditions were the destructive agents in the West Indies.

The years of the cycles of disease were the years of overcrowding, when military exigencies demanded that large garrisons should hold the islands. The sanitary conditions at all times were, without exception, infamous.

There was a great mortality from scorbutic dysentery, which was almost entirely owing to diet.[1] Up to within a comparatively late date, the troops were fed on salt meat three, and sometimes five, days a week, and the supply of fresh vegetables was scanty. It required all the influence of Lord Howick, the then Secretary of War, to cause fresh meat to be issued, though it had been pointed out by successive races of medical officers that fresh meat was not only more wholesome but was actually cheaper. The result of an improvement in the diet was marvellous; the scorbutic dysentery at once lessened, and the same amount of mortality from this cause is now never seen. Another cause of dysentery was to be found in the water, which was impure from being drawn from calcareous strata, or was turbid and loaded with sediment. The substitution of rain-water has sufficed in some stations to remove the last traces of dysentery.

If the food and water were bad, the air was not less so. Sir Alexander Tulloch has given a picture of a single barrack at Tobago, said to be the "best in the whole Windward and Leeward command,"[2] the figures of which tell their own tale.

Barrack at Tobago in 1826.—Superficial space per man, 22½ feet; breadth, 23 inches; cubic space, 250 feet.

The men slept in hammocks touching each other. In these barracks, crowded as no barracks were even in the coldest climates, there was not a single ventilating opening except the doors and windows; the air was fœtid in the highest degree. With this condition of atmosphere it is impossible not to bring into connection the extraordinary amount of phthisis which prevailed in the soft and equable climate of the West Indies. There was more phthisis than in England, and far more than in Canada. The first great improvement was made in 1827, when, iron bedsteads being introduced, each 3 feet 3 inches wide, greater space was obliged to be given to each man.

Every arrangement for removal of sewage was barbarous, and in every barrack sewage accumulated round the buildings, and was exposed to heat and air. When yellow fever attacked a regiment, every stool and evacuation was thrown into the cesspools common to all the regiment; and in this way the disease was propagated with great rapidity, and was localised in a most singular manner, so that, a few hundred yards from a barrack where men were dying by scores, there would be no case of fever. In spite of this, it was many years before the plan of at once evacuating a barrack where yellow fever prevailed was adopted.

The barracks themselves were usually very badly constructed, and when in some cases the architects had raised the barracks on arches from the ground, in order to insure perflation of air below the buildings, the arches were blocked up or converted into store-rooms; and the barracks, with spaces thus filled with stagnant air beneath them, were more unhealthy than if they had been planted on the ground.

The localities for barracks were often chosen without consideration, or for

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[1] This is pointed out in the *Statistical Report* (1838) *on the West Indies*, by Tulloch and Balfour; and it is believed that the improvement in the diet was in a great measure owing to these gentlemen.

[2] *Report*, 1838.

military reasons,[1] into which no consideration of health entered. Almost all were on the plains, near the mercantile towns, where the soil was most malarious, and the climate hottest and most enervating. Malarious fevers were, therefore, common.

To all these causes of disease were added the errors of the men themselves. For the officers there existed, in the old slave times, the greatest temptation. A reckless and dangerous hospitality reigned everywhere; the houses of the rich planters were open to all. A man was deemed churlish who did not welcome every comer with a full wine, or more often a brandy, cup.

In a climate where healthy physical exertion was deemed impossible, or was at any rate distasteful, it was held to be indispensable to eat largely to maintain the strength. To take two breakfasts, each a substantial meal, was the usual custom; a heavy late dinner, frequently followed by a supper, succeeded; and to spur the reluctant appetite, glasses of bitters and spirits were taken before meals.

The private soldiers obtained without difficulty abundance of cheap rum, which was often poisoned with lead. Drunkenness was almost universal, and the deaths from delirium tremens were frequent and awfully sudden. The salt meat they were obliged to eat caused a raging thirst, which the rum bottle in reality only aggravated.

To us these numerous causes seem sufficient to account for everything, but in former days an easier explanation was given. It was held to be the climate; and the climate, as in other parts of the world besides the West Indies, became the convenient excuse for pleasurable follies and agreeable vices. In order to do away with the effects of this dreaded climate, some mysterious power of acclimatisation was invoked. The European system required time to get accustomed, it was thought, to these climatic influences, and in order to quicken the process, various measures were proposed. At one time it was the custom to bleed the men on the voyage, so that their European blood might be removed, and the fresh blood which was made might be of the kind most germane to the West Indies. At other times an attack of fever (often brought on by reckless drinking and exposure) was considered the grand preservative, and the seasoning fever was looked for with anxiety. The first statistical report of the army swept away all these fancies, and showed conclusively that instead of prolonged residence producing acclimatisation and lessening disease, disease and mortality increased regularly with every year of residence.

The progress of years has given us a different key to all these results. It is now fully recognised that in the West Indies, as elsewhere, the same customs will insure the same result. Apart from malaria, we hold our health and life almost at will. The amount of sickness has immensely decreased; occasionally in some stations which used to be very fatal (as at Trinidad) there has not been a single death in a year among 200 men. Among the

[1] The history of the old St James's Barracks in Trinidad is too remarkable to be passed over. It was determined to build a strong fort—a second Gibraltar—on the lower spurs of the hills overlooking the plain where the barracks now stand. When the works had been carried on for some time, it was discovered that they could not hold the troops. The barracks were then ordered to be placed on the plain, under cover of the guns of the fort. Before the fort was quite finished, it was found to be so unhealthy that neither white or black men could live there, and it was abandoned. The barrack, it is said, was not then commenced; yet, though the reason for placing it in that spot had gone, it was still built there, on a piece of ground near two marshes (Cocorite and the Great Western Marsh), below the general level of the plain, and exposed to the winds from the gullies of the neighbouring hills. Yet this bad position, so fruitful of disease, was in reality less injurious than the bad local sanitary arrangements of the old St James's Barrack itself.

measures which have wrought such marvels in the West Indies have been—

1. A better supply of food; good fresh meat is now issued, and vegetables, of which there is an abundance everywhere.

2. Better water.

3. More room in barracks, though the amount of cubic space is still small.

4. Removal of some of the stations from the plains to the hills, a measure which has done great good, but which can explain only a portion of the improvement. The proper height to locate troops is by most army surgeons considered to be at some point above 2500 feet.

5. Better sewage arrangements, and more attention generally to sanitary conservancy.

6. A more regular and temperate life, both in eating and drinking, on the part both of officers and men.

7. The occupancy of the unhealthy places, when retained as stations, by black troops.

8. A better dress. It is only, however, within recent years that a more suitable dress has, at the instance of the late Sir J. B. Gibson, formerly Director-General A.M.D., been provided for the West Indian Islands.

The army stations in the West Indies are Jamaica, Barbadoes, Trinidad, St Vincent. British Guiana, on the mainland, is part of this command. There are small parties of artillery and some black troops in Honduras and the Bahamas.

The period of service is now three or four years: formerly it was eleven or twelve, but this was altered after the first statistical report. Usually the Mediterranean regiments pass on to the West Indies, and subsequently to Canada. The total number of men serving in the West Indies is now very small.

The proper time for arriving in the West Indies is in the beginning of the cold season, viz., about the beginning of December, when the hurricanes and autumnal rains are usually over.

Jamaica.

Present strength of white garrison, 200 to 300; black troops, 500 to 600 Population of island estimated at 560,000. A range of lofty hills (Blue Mountains) divides Jamaica into two parts, connected by a few passes. The troops were formerly stationed chiefly in the south plains, at Kingston (30,000 inhabitants), Port-Royal, Spanish Town, Up-Park Camp, Fort-Augusta, &c. After the Maroon war in 1795 some troops were stationed at Maroon Town (2000 feet above the sea), on the north side, and at Montego Bay. Subsequently Stoney Hill (1380 feet above the sea), at the mouth of one of the passes, was occupied.

Since 1842 some, and now nearly all, the troops are at Newcastle, in the hills, 4000 feet above the sea, with detachments at Kingston and Port-Royal. The other stations are now disused for white troops. The sanitary condition at Newcastle was formerly not good; the sewage arrangements are very imperfect; it is now somewhat improved.

Climate.—The climate is very different at the different stations. At Kingston (sea-level)—temperature, mean of year = 78°; hottest month, July, mean = 81°·71; coldest month, January, mean = 75°·65; mean yearly fluctuations = 6°·06. Undulations trifling. The climate is limited and equable. At Newcastle the mean annual temperature is about 66°; hottest

month, August = 67°·75; coldest month, February = 61°. The diurnal range is considerable, but the annual fluctuation is trifling (about 6°). The mean of the year is therefore much lower than on the plains; the amplitude of the yearly fluctuation about the same; the diurnal change greater.

Humidity.—This is considerable in the plains—often from 80 to 90 per cent. of saturation = 7 to 9 grains of vapour in a cubic foot. At Newcastle the mean yearly dew-point is about 60°; the amount of vapour in a cubic foot of air is 5·77 grains; the mean yearly relative humidity is 68 per cent. of saturation.

Rain.—Amount on the plains = 50 to 60 inches, in spring and autumn, viz., April and May, and October and November. Showers in July and August.

Winds.—Tolerably regular land winds at night, and sea breezes in the hot and dry months during the heat of the day. The central chain of mountains turns the north-east trade wind, so that it reaches the south side diverted from its course; from December to February the wind is often from the north, and brings rain and fogs ("wet northers"). The south-west wind in April and May is very moist. The hurricane months are from the end of July to the beginning of November. The climate in the plains is therefore hot, equable, and humid.

Health of the Black Civil Population.

Of the specific diseases, smallpox and the other exanthemata are common. Spotted typhus is said to be unknown; enteric fever is said to be uncommon, but is probably more common than is supposed. Influenza has prevailed at times, and also the so-called dandy or polka (Dengue). Cholera has prevailed severely. Malarious fever is common over the whole of the south plains. Yellow fever is common, though less frequent and severe among the blacks than the whites. Dysentery is common, though it has always been less frequent than among the troops. Organic heart disease is frequent. Liver diseases are uncommon. Spleen disease, in the form of leucocythæmia, is common among the blacks (Smarda). Gout is said to be frequent, and scrofula and rickets to be infrequent. Syphilis is not common, but gonorrhœa is. Cancroid of the skin and elephantiasis of the Arabs (pachydermia) are common. Leprosy is also seen.

Health of the Troops.

In the years 1790–93 the annual mortality of the white troops varied in the different stations from 111 (Montego Bay) to 15·7 per 1000 of strength at Stoney Hill (1380 feet above sea-level). In the years 1794–97 the mortality was much greater; the most unhealthy regiment in the plains lost 333, the most healthy 45·4, per 1000 of strength; at the hill station of Maroon Town (2000 feet) the mortality was, however, only 15·6 per 1000. In the years 1817–36 the mean mortality was 121·3; the mean of the four healthiest years gave 67, and of the four unhealthiest years 259 per 1000. The causes of death in these twenty years were—

Fevers, . . .	101·9	per 1000 of strength.
Lung diseases, . .	7·5	„
Bowel complaints, . .	5·1	„
Brain disease, . .	2·6	„
Liver diseases, . .	1·0	„
Other complaints, . .	3·2	„
	121·3	„

The admissions in these years were 1812 per 1000 of strength. In 1837–55 the following were the mean results:—Mortality per 1000 of strength—white troops, 60·8; black troops, 38·2. Admissions per 1000—white troops, 1371; black troops, 784. So that the mortality had declined one-half.

In 1864 the mortality was much below the home standard. In 1867 it ran up nearly to the old amount, from the prevalence of yellow fever, which in that year prevailed again in Newcastle, and caused a greater loss than it had done in 1860. The statistics of the white troops were—

Years.	Loss of Strength per 1000 per annum.			Loss of Service per 1000 per annum.		
	Total Deaths.	Deaths from Disease.	Invalids.	Admissions.	Mean daily Sick.	Days in Hospital to each Sick Man.
1861–70 (10 years),	20·36	...	27·6	930·8	40·63	16·10
1871,	13·51	13·51	30·4	...	32·43	15·17
Highest in 1867,	71·09	69·80	45·91	1192·9	78·95	21·95
Lowest in 1864,	7·35	5·88	...	...	...	...
In 1875 the death-rate was,	12·99	...	...	...	...	...

Since 1875 no separate return is furnished in the *A.M.D. Reports*. An increase in admissions and mortality occurred in 1865 and 1866, owing to the exposure of the troops in the time of the negro disturbances, and their subsequent partial location on the plains.

Before this period Jamaica contrasted favourably even with home service, and particularly so with India.

A decrease of admissions in 1859–64 was chiefly owing to the comparatively small number of cases of paroxysmal disease, a decline consequent on the removal of most of the troops from the plains (in 1859 Newcastle gave 29·1 admissions, and Port-Royal, on the plain, 443·5 per 1000 of strength, from malarious disease). In 1863 some white troops were sent to Up-Park Camp, and furnished a large number of malarious cases (547·6 admissions per 1000 of strength), while at Newcastle they were only 48 per 1000. The decrease in the mortality in the years 1859–64 was owing to lessened fever and dysentery. Among the black troops there is now greater sickness and mortality than among the whites; the mortality in 1837–55 was 38·2 per 1000; in 1859–65 it was 27·33; in 1866, 23·03; in 1875 it was only 14·67. There is among these troops a large mortality from paroxysmal fevers, phthisis, and diseases of the alimentary canal; and it is evident that their condition requires a close examination.

The mortality of the white troops shows a marked increase with age.

The following seem to be the most important points connected with the white troops which require notice.

It is impossible to avoid paroxysmal fevers without placing all the troops in the hills, and it is very desirable Newcastle should be made the only station for white troops.

The possibility of yellow fever occurring at an elevation of 4000 feet was shown by the appearance of yellow fever at Newcastle in 1860 and 1867. In 1860 occurred the remarkable instances of contagion on board the ships "Icarus" and "Imaum" described by Dr Bryson. Whether yellow fever was imported into Newcastle or not was a subject of discussion; it certainly appears probable that it was carried there; but the important point for us is that mere elevation is not a perfect security. There were, however, only

a small number of cases. In 1867, when yellow fever again appeared at Newcastle, it was imported, apparently, from Kingston and Up-Park Camp.

In the returns for a number of years, cases were returned as "continued fever"; it had never been clearly made out whether or not these were cases of enteric fever until 1873–4, when a sharp epidemic occurred at Newcastle.

Formerly there was a large number of cases of phthisis; phthisis is now uncommon; in 1817–36 lung diseases (almost entirely phthisis) caused 7·5 deaths per 1000 of strength, or more than in England. In 1859–66 the ratio was only 1·42 per 1000 of strength; and in 1861, out of 636 men there was not a single death, though four men were sent home with consumption. In 1865 there was no death; eight men were sent home.

At Newcastle there occurred for some years an excess of affections of the alimentary canal, chiefly indigestion; at present these have lessened, but it would be important to make out the cause. In 1860 there was not a single admission from dysentery at any station.

In the worst times in Jamaica it was always remarked that there was rather a singular exemption from acute liver disease; very few cases appear in the returns under hepatitis; whether this is a matter of diagnosis, or whether there was really an immunity compared with India or the Mauritius, is a question of great interest which cannot now be solved. At present, liver disease unconnected with drinking is uncommon.

There is still too much drinking, and the medical officers have strongly advised the issue of beer instead of the daily dram.

Venereal diseases have never prevailed much in Jamaica; they have caused, on an average, from 70 to 90 admissions per 1000 of strength. In 1862 there were only 47 admissions per 1000 of strength. On an average in 1859–65, enthetic diseases gave 118 admissions per 1000. This is owing to the connection usually formed between the black women and the soldiers, and to a lessened amount of promiscuous intercourse.

The history of the years 1865–67 shows that the greatest care and the most judicious arrangement of the men is necessary to guard against a recurrence of the old evils.

The black troops gave a mortality of 24·6 per 1000 (mean of ten years, 1861–70), especially from phthisis.

Trinidad.

Strength of garrison, 200 men. Civil population (in 1881) about 153,000.

Geology.—Tertiary formation of Miocene age; central range of hills is an indurated formation of Cretaceous age; the northern littoral range consists of micaceous slates, sandstones, limestones, and shales. The highest hill is 3012 feet; the central hill (Tamana) is 1025; $\frac{1}{17}$th of the island is swampy.

Climate.—Temperature of the plains: Mean of year about 79°·3; coldest month, January = 78°; hottest month, May = 81°·5; next hottest, October = 80°·4. Mean annual fluctuation, 3°·5. The climate is therefore very equable and limited. There are, however, cold winds from the hills blowing over small areas.

Hygrometry.—Mean dew-point, 75°·1; mean relative humidity = 81 per cent. of saturation; mean weight of vapour in a cubic foot = 9·4 grains; most humid month is May, as far as the amount of vapour is concerned. Month with greatest relative humidity, August.

Winds from east to north-east and south-east. West winds rare, and oppressive.

Rain on the Plains about 60 to 70 inches. Greatest rainfall in one day, 4·67 inches. Dry season, December to May. June and July showery. Heavy rain in August, September, and October.

Sanitary Condition.—St James's Barrack is on a depression on an alluvial soil three miles from Port of Spain, the capital; it is one mile from the Cocorite, and three from the Great Western Swamp; the drainage, for many years most defective, is now improved, as the main sewer is carried to the sea. On many occasions yellow fever has prevailed in this barrack, and nowhere else in the island; the last occasion was in 1858–59, and then it was proposed by Dr Jameson (the principal medical officer) to erect barracks on a spot 2200 feet above sea-level.

The capital, the Port of Spain (32,000 inhabitants), is built at the principal outfall of the island; it is on a low and unhealthy plain. Formerly it was so unhealthy as to be scarcely habitable, but after being well drained and paved by Sir Ralph Woodford, it has become much healthier. This was the result of great sanitary efforts in a very unpromising locality, and should be a lesson for all climates.

There is still, however, much malarious disease, dysentery, and at times yellow fever; but this last disease has occasionally been very severe at St James's Barracks without a single case being seen in Port of Spain. The ascent of the malaria from the barrack plain is certainly more than 500, and probably as much as 1000 feet.

Diseases of Troops.—The state of health has been and is very similar to that of Jamaica, with, however, a large percentage in former years both of phthisis and diseases of the stomach and bowels, chiefly dysentery.

In the years 1817–36, the average mortality of the white troops was 106·3 per 1000 of strength, and of these deaths there were—

From fevers,	61·6
Lung diseases,	11·5
Diseases of stomach and bowels,	17·9
Dropsies (probably partly malarious, partly renal),	7·7
Brain diseases (especially from intemperance),	4·7
Liver diseases,	1·1
All other diseases,	1·8
	106·3

As in Jamaica, the statistics of the white troops of late years tell a very different story.

In 1859 there was an outbreak of yellow fever, and the deaths from disease rose to 84·27 per 1000. In the next seven years (ending 1866) the average number was 7·48 deaths from disease per 1000. In two years (1860 and 1865) there were no deaths.

Even in 1859, when the mortality was so large, there were only 10 deaths from yellow fever among 190 men, while there were no less than 4 deaths from delirium tremens.

Among the diseases in the returns, the largest item is malarious fever; there are also cases of "continued fever," as in Jamaica; and this term, in fact, has never been absent from the reports. Is this enteric fever? In all probability it is, as unequivocal enteric fever does occur in Trinidad.[1] A considerable number of cases of dyspepsia are admitted; in 1860 there were 16 cases out of 221 men, or 72 per 1000 of strength. In 1862 there were 103 per 1000 admissions, from "digestive" diseases. Venereal diseases

[1] Dr Stone's paper in the *Medical Times and Gazette*, Feb. 1860.

have always been low; in 1860, 1861, 1862, and 1864 there were only 49·8, 44·4, 20·6, and 63·8 admissions per 1000 of strength. Dysentery is now infrequent. In 1860, out of 221 men, and 1861, out of 225 men, there was not a single case. In 1864, out of 235 men, there was only 1 case. In 1865 there were no admissions from phthisis. Phthisis is much less common, yet in some years there is still too much of it. Separate statistics are no longer available from the *A.M.D. Reports.*

It is evident that if Dr Jameson's suggestion is acted upon, and the troops are removed to the hills, malarious fever will disappear, and yellow fever can be prevented. In such a case, if the men will abstain from drinking, this island, which formerly killed rather more than 1 man in every 10 yearly, will be one of the healthiest spots in the world.

The black troops are now less healthy than the white, having in 1859–65 an annual mortality of nearly 20 per 1000, of which 18 were from disease. Their condition requires looking into. Of late years a very small number of black troops have been stationed at Trinidad.

The invaliding from Trinidad is combined in the Army Reports with that of the other islands of the Windward and Leeward commands.

Barbadoes.

Strength of garrison, 300 to 400 men. Civil population (in 1881), 172,000.

Geology.—Limestone (coralline); sandstone (Tertiary); beds of bituminous matter and coal (Tertiary); clay in parts (especially in the hilly district called "Scotland").

An open country, well-cultivated, no marshes except a small one at Græme Hall, one mile to the east of St Ann's Barracks.

The country is divided into two parts: a mountainous district termed "Scotland," and a lower country consisting of a series of five gigantic terraces, rising with some regularity one above the other. The highest hill is 1100 feet.

Climate of the Plain.—Temperature: mean of year, 80°; hottest month (October), 83°; coldest month (January), 78°; mean yearly fluctuation, 5°. Climate equable and limited. Relative humidity, 70 per cent.

Wind.—N.E., trade, strongest in February to May; weak in September to November inclusive; hurricane month, August.

Rain.—About 56 to 58 inches on an average, but varying a good deal in the autumn chiefly, though there is rain in all months, but much less. The dry season is from December to May.

Water.—Formerly supplied from wells; it was highly calcareous. At present good water is supplied by a water company. Rain-water is also collected in tanks.

Sanitary Condition.—St Ann's Barracks are placed above one and a half miles from Bridgetown, on the sea; the locality and the construction of the barracks have been much complained of, and a position in the hills advised.[1] Arrangements for sewering and the water supply were both formerly bad; considerable improvements have been made, and, since 1862, 30,000 gallons are supplied daily to St Ann's Barracks. It is a limestone water, containing carbonate of lime, but no sulphate of lime, and is remarkably free from organic matter. The total solids are 18·72 grains per gallon. The

[1] For an extremely good and concise account of Barbadoes, see Dr Jameson's Report in the *Army Medical Report* for 1861, p. 261.

troops are still too much crowded in barracks, the allowance being under 600 cubic feet. Since 1872 new latrines (Jennings' pattern) have been provided and the old ones closed.

Formerly vegetables were very deficient in Barbadoes, and even now there is some difficulty in procuring them. They are often imported from other islands.

Diseases among Civil Population.—Yellow fever has appeared frequently. It is not so frequent as formerly; it used to be expected every four years.

Barbadoes and Trinidad contrast greatly in the freedom from marshes of the one, and the existence of marshes and malarious diseases in the other; but Barbadoes has had as much yellow fever as Trinidad.

Dysentery was common formerly, partly from bad water; influenza has been epidemic several times. Barbadoes leg, or elephantiasis of the Arabs, is frequently seen. Leprosy, or elephantiasis Græcorum, is also not very uncommon. Variola and Pertussis have from time to time been very bad.

Hillary, in 1766, described a "slow nervous fever," under which term our enteric fever appears to have been indicated by most writers of that period. His description is not quite clear, but resembles enteric fever more than any other. He also speaks of "diarrhœa febrilis." Can this have been enteric?

Dracunculus was formerly very frequent, and Hillary attributes it to the drinking water, and states that there were some ponds, the water of which was known to "generate the worm if washed in or drunk."

Yaws used to be common.

Colica pictonum was formerly frequent.

Diseases of Troops.—Yellow fever has several times been very fatal.

Scorbutic dysentery, arising from the wretched food, was formerly very frequent, and appears from Sir Andrew Halliday's work to have been very bad even in his time (1823 to 1832).

From 1817 to 1836 (20 years)—

Average mortality (white troops),	58·5 per 1000 of strength.			
Greatest ,, ,,	204	,,	,,	(in 1817).
Least ,, ,,	18	,,	,,	(in 1823).

In 1817 there were 1654 men on the island, and yellow fever broke out. In 1823 there were only 791.

Of late years, as in all the other islands, the sickness and mortality has been comparatively trifling.

In 1859–65 the total deaths were 6·98 per 1000, and in 1866 they fell to 3·28 per 1000, which was only $\frac{1}{3}$rd the mortality of home service. The highest mortality of late years was in 1862, viz., 16·77; the average number of admissions is about 1200.

In 1864 there was an outbreak of a mild fever, termed "remittent"; the nature is unknown; no case was fatal.

The increased mortality of 1862 was owing to yellow fever. It appeared first among the civil population in Bridgetown, and afterwards attacked the troops in the (stone) barracks. As it continued to spread, the men were moved out and placed under canvas, with the best effects. A remarkable feature of this epidemic was that the officers suffered in attacks six-fold more than the men, and had a mortality more than twenty-fold. The women also suffered three-fold more than the men. Formerly the case would have been reversed. In 1861 there were only two deaths out of 787 men, one from phthisis and one from apoplexy; and in 1864 there were also only two deaths (diarrhœa and phthisis) among 930 men.

Dysentery is now uncommon.

The great improvement to be made at Barbadoes is decidedly a complete change of barracks. The persistent recurrence of yellow fever in these old barracks, with their imperfect arrangements, shows them to be the main cause of the appearance of the disease. The saving in the cost of a single epidemic would amply repay the outlay.

As in the other islands, the black troops are now much more unhealthy than the white, and the sanitary condition of their barracks and their food evidently requires looking into. Phthisis and chronic dysentery are the chief diseases causing mortality. The average of 1859–64 gave 1015 admissions and 20·46 deaths per 1000 of strength. In 1865 there were 22·64 deaths per 1000 of strength, or, excluding violent deaths, 20·49; of these phthisis caused 14·34, or no less than 70 per cent. of total deaths.

No separate information is now available from the *A.M.D. Reports*.

St Lucia.

Strength of garrison = 100 men, now usually black troops. Civil population (in 1871), 36,610.

St Lucia is divided into two parts: Basseterre, the lowest and most cultivated part, is very swampy; Capisterre, hilly, with deep narrow ravines full of vegetation. The climate is similar to that of the other islands, but is more rainy and humid.

Diseases of the White Troops.—From 1817–36: average strength, 241; average deaths, 30 = 122·8 per 1000 of strength. Of the 122·8 deaths, 63·1 were from fevers, 39·3 from bowel disease; and 12·5 from lung disease.

Pigeon Island (a few miles from St Lucia) was formerly so unhealthy that on one occasion 22 men out of 55 died of dysentery in one year, and of the whole 55 men not one escaped sickness. The cause is supposed to have been bad water. Now Pigeon Island is considered healthy.

Although the mortality was formerly so great, St Lucia has been very healthy for some years.

In 1859, mean strength of white troops, 96; admissions, 113; and there was not a single death, although, if the mortality had been at the rate of the twenty years ending 1836, 12 men would have died.

Better food, some improvement in barracks, and the use of rain instead of well water, have been the causes of this extraordinary change.

22 men were admitted with "continued fever," 18 with ophthalmia, and only 2 with venereal.

In 1860 there was no case of dysentery and only two of diarrhœa among 100 men in this island, where formerly there would have been not only many cases, but 4 deaths. One man died from phthisis, or at the rate of 10 per 1000.

In 1861, out of 94 men, there was one death from jaundice, or at the rate of 10·6 per 1000.

In 1862 there were 88 men on the island; one man was drowned; there was no death from disease. No case of jaundice was admitted.

In 1863 there were 55 men, and one death from accident; there were 64 admissions, of which 15 were accidents.

The total death-rate among the white troops in the West Indian command was, in 1880, 8·68 per 1000, of which 5·79 only were due to disease; invalids sent home, 42·43 per 1000, of whom 12·54 were finally discharged.

British Guiana (252,000 *inhabitants in* 1881).

No white troops are at present stationed at Demerara.

This station in the West Indian command is on the mainland, extending from the equator (nearly) to 10° N., 200 to 300 miles, and inland to an uncertain distance.

It is a flat alluvial soil of clay and sand, covered with vegetation.

The water of Georgetown is not good; it is drawn from a freshwater lake and an artesian well; the water from this well contains a good deal of iron.

Trade winds from N.E. and E. for nine months. In July, August, and September, S.E. and S. and land-winds. This is the unhealthy season.

Two wet seasons, January and June; the last is the longest.

Temperature of summer, 86°; of winter, 82°. Rain about 100 inches.

Formerly there was an enormous mortality among the troops from yellow fever and scorbutic dysentery. The men used to have salt meat five times a week.

The climate is most highly malarious, but this does not cause much mortality.

Yellow fever has prevailed here several times. On one occasion (1861) the troops were moved out and encamped at some distance from Georgetown; they escaped (7 mild cases only), although they were on a swampy plain.

In 1817–36 the average deaths were 74 per 1000 of strength.

In 1859, out of a mean strength of 143, there were 156 admissions = 1091 per 1000 of strength; 2 deaths = 13·9 per 1000 of strength. One death from apoplexy, one from drowning. The deaths from disease were only 6·9 per 1000. Of the 156 admissions, no less than 81 were from malarious disease, or at the rate of 519 per 1000 of strength, or nearly one-half the total admissions.

In 1860, 1861, and 1862 the admissions from malarious disease continued high (673, 1380, and 1104 per 1000 of strength), the mortality was very small, being only 6·6 per 1000 in each year; in fact, the single death in 1860 and in 1861 was in the one year from "acute hepatitis," and in the other from accident. In 1862, in spite of the immense malarious disease, there was no death.

Subsequently to 1861 it appears that scattered cases of yellow fever occurred among the shipping and in the town every year; in 1866 there was an outbreak among the white troops. In eight weeks 16 deaths occurred among 72 men, or 22 per cent.[1]

Some important lessons are drawn from the medical history of this station. It has been shown that even in a highly malarious country yellow fever may be evaded by change of ground, although the men are obliged to encamp on a swamp. Another remarkable point is the very small mortality attending the paroxysmal fevers. It would be very interesting to know the future history of such men, but it cannot be doubted that the lessened mortality since former years must be owing to better treatment.

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[1] A full inquiry was made into this outbreak; it was, as so frequently happens, localised, for the troops were suffering severely while the health officer for the port (Dr Scott) states in his evidence (*Report of the Commissioners appointed to Inquire into the Outbreak of Yellow Fever at Demerara in* 1866, p. 25) that the cases in town were "very few" at the time. The barracks were badly circumstanced in various ways, particularly in having removal of sewage on a trench system, into which the latrines opened, and which trenches were intended to be kept clean by flushing; they were, however, in a very foul state, and were merely open cesspools; and the evidence of Surgeon-Major Hutton (*Report*, p. 37) clearly points out that a thoroughly good system of dry removal is the proper plan for this colony. Whether this and the other unsanitary conditions gave its local development to the yellow fever was a matter of doubt in the colony, but they are precisely the same conditions which have been so frequently seen in West Indian outbreaks,—a foul soil, and, in addition, open cesspools exposed to the intense heat of a tropical sun, and to the influence of a moist atmosphere and a moist soil. On this occasion the troops were not removed from the barracks until too late.

The extent of malarious disease shows how desirable it is to avoid sending white troops to Demerara.

In French Guiana, Dr Laure, besides malarious fevers, describes enteric fever to have occurred for some short time after the arrival of French political prisoners after the *coup d'état* of 1851. It then disappeared.

Bahamas and Honduras.

The black troops garrison both those places, and show a degree of mortality nearly the same as in the other stations, the amount of phthisis being very great. In 1862, at the Bahamas, there were no less than 4 deaths from phthisis out of a strength of 439, or at the rate of 9·1 per 1000 of strength; there were also 3 deaths from pneumonia and 1 from pleurisy. In the years 1859–66 the average deaths from tubercular diseases per 1000 men were 11·04 yearly, and from other diseases of the lungs 5·86; out of 100 deaths, 60 were from diseases of the lungs. This is evidently a matter for careful inquiry.

At Honduras, among the black troops, the deaths from tubercular disease, in 1859–66, were 4·04 per 1000 of strength.

Taking the West Indian command in 1884 (a year free from yellow fever), the admissions per 1000 for disease alone were 604, and the deaths 9·27. There was no death from any form of fever.

SECTION III.

BERMUDA.

Strength of garrison (1884), about 1551 men. Civil population (in 1881), 13,948.

Climate.—Hot, equable, and rather limited.

Temperature.—Mean of year, 74°; hottest month (July), 83°·5; coldest month (February), 64°·5; amplitude of yearly fluctuation 19°. Relative humidity about 74 per cent.

The sanitary condition was formerly very bad; there were no sewers, and no efficient dry method of removal. Now matters are much improved, and in later years the health of the troops has been good. Rain-water is used for drinking.

Diseases of the Troops.

Years.	Loss of Strength per 1000 per annum.			Loss of Service per 1000 per annum.		
	Total Deaths.	Deaths from Disease.	Invaliding.	Admissions.	Mean daily Sick.	Days in Hospital to each Sick Man.
1817–36,	28·8	...	...	768	...	...
1837–46,	35·5	...	...	1080	...	...
1861–70 (10 years),	26·02	...	20·6	764·3	39·54	15
1864 (highest; yellow fever year),	169·54	168·83	...	...	...	...
1860 (lowest),	8·55	5·70	...	...	...	...
1865–74 (10 years),	15·04	...	21·92	716·5	35·39	18·27
1870–79 (10 years),	8·96	...	20·45	637·1	32·62	18·69
1879–83 (5 years),	7·03	5·36	16·79	650·2	35·45	19·90
1884,	10·96	8·39	2·57	617·6	32·40	19·16

The history of the West Indies may be applied to Bermuda, though, with the exception of yellow fever years, it never showed the great mortality of the West Indies. There is no great amount of paroxysmal fevers; in ten years (1837–46) there were only 29 admissions out of an aggregate strength of 11,224 men. In ten years (1870–79) there were only 15 admissions out of 18,974, or at the rate of 0·8 per 1000. In five years (1879–83) the ratio per 1000 was 1·9, in 1884 it was 0·6, being 1 case in 1551 men.

Yellow fever has prevailed seven times in this country, viz., in 1819, 1837, 1843, 1847, 1853, 1856, and 1864.

The history of the yellow fever in 1864 is given in detail by Dr Barrow.[1]

The total mortality was 14 officers, 173 men, 5 women, and 4 children. The deaths to strength were, among the officers, 189, and among the men, 149 per 1000. The officers' mortality was owing to a large number of deaths among the medical officers.

The town of St George's, in Bermuda, presents every local condition for the spread of yellow fever; the town is quite unsewered; badly supplied with water; badly built.

"Dandy fever," or break-bone (Dengue), has prevailed several times.

"Continued fevers" (often in large part enteric) have always prevailed more or less at Bermuda. In the ten years 1837–46 they gave 1004 admissions out of 11,224 men, or 88 per 1000 of strength, being much greater than at home. In ten years (1870–79) there were 884 admissions out of 18,974, or 47 per 1000; in 1879–83 the admissions were, for enteric fever 9·9, other continued fever 31·3 per 1000; deaths (enteric only) 1·91.

In 1859 there were only 11 cases of "continued fever" out of 1074 men; but in 1860 "continued fever" prevailed severely (209 cases in 1052 men). It was of a mild type, and caused little mortality. It was probably not enteric, but its nature was not definitely determined. It prevailed in September, October, and November. It is said that the drainage was defective at Hamilton.

In 1884, admissions for enteric fever 40, for other continued fevers 30·9 per 1000; deaths (enteric only) 6·45 per 1000, or 78 per cent. of total deaths from disease. This inordinate mortality seems to have been connected with a heavy rainfall following an unusually dry summer, and the consequent accumulation in various cess-pits—on this being removed and the cess-pits cleaned the epidemic ceased.

Formerly tuberculous diseases caused a considerable mortality. In the years 1817–36 diseases of the lungs gave a mortality of no less than 8·7 per 1000 of strength. In 1837–46 the lung diseases gave a yearly mortality of 8·3 per 1000 of strength. Of late years the amount has decreased. The admissions and deaths respectively were 10·5 and 2·6 in the seven years 1859–65. In 1870 the deaths from phthisis were 1·57, and in 1871 no less than 5·19 per 1000 of strength; in 1875 they were 1·58. In five years (1879–83) they were 1·19, discharged as invalids 2·62, total 3·81; in 1884, deaths 0·64 (one case out of 1551 men), no invalids.

Diarrhœa and dysentery were also formerly very common, but of late years there has been a great decrease. Diseases of the eyes are common.

There has always been much intemperance, and a large number of deaths from delirium tremens. This was the case even in 1866; there were no less than 5 deaths out of a total of 28.

Venereal diseases have averaged from 55 to 80 per 1000 of strength, but latterly have diminished.

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[1] *Army Medical Reports*, vol. v. p. 290.

In considering the sanitary measures to be adopted at Bermuda, it would seem that drainage and ventilation are still most defective, and that means should be taken to check intemperance. If yellow fever occurs, the measures should be the same as in the West Indies.

SECTION IV.

NORTH AMERICAN STATIONS

Sub-Section I.—Canada.[1]

The usual garrison used to be from 3000 in profound peace to 10,000 or 12,000 in disturbed times. In 1871 the troops were withdrawn from Canada and concentrated at Halifax.

Lower Canada.

Chief Stations—1. *Quebec* (62,000 *inhabitants*).

Temperature.—Mean of year, 41°; hottest month (July), 71°·3; coldest (January), 11°. Annual fluctuation, 60°·3.

The undulations of temperature are enormous. In the winter, sometimes, there is a range of 30, 40, and even more degrees in twenty-four hours, from the alternation of northerly and southerly winds. In one case the thermometer fell 70° in twelve hours. The mercury is sometimes frozen.

The mean temperature of the three summer months is 69°; winter months 12°·8. The climate is "extreme" and variable.

Rain.—About 36 to 40 inches. The air is dry in the summer, and again in the depth of winter.

Barracks.—Built on Lower Silurian rocks. No ague is known, though the lower town is damp.

Amount of cubic space small. Casemates in citadel very bad, damp, ill ventilated, ill lighted.

2. *Montreal* (140,000 *inhabitants*).

Temperature.—Mean of year, 44°·6; hottest month (July), 73°·1; coldest (January), 14°·5. Annual fluctuation, 58°·6. The undulations are very great, though not so great as at Quebec.

Mean of the three summer months, 70°·8; of the three winter months, 17°·2.

Rain.—36 to 44 inches.

Barracks.—Bad; very much overcrowded.

In Lower Canada are also many smaller stations.

Upper Canada.

Chief Stations—1. *Toronto* (86,000 *inhabitants*).

Temperature.—Mean of year, 44°·3; hottest month (July), 66°·8; coldest (February), 23°·1. Difference, 43°·7. Great undulations.

Rain.—31·5 inches.

[1] For an excellent account of the Canadian stations, see Sir W. Muir's Report in the *Army Medical Report* for 1862, p. 375.

The town stands on ground originally marshy. The new barracks are built on limestone rocks of Silurian age. Average cubic space only 350. Drainage bad.

Intermittent fevers among the civil population; not very prevalent among the troops.

2. *Kingston* (14,000 *inhabitants*).

Temperature.—Mean of year, 45°·8.

Malarious.

London, Hamilton, and several smaller stations—Fort George, Amherstberg, &c.—were also occupied at one time.

Diseases of the Civil Inhabitants.

Formerly ague was prevalent in Upper Canada, especially in Kingston; it is now much less. At Montreal ague used to be seen; now it is much less frequent. It prevails from May to October, and is worst in August.

If the summer isothermal of 65° be the northern limit of malaria, both Quebec and Montreal are within the limit; yet the winter is too severe, and the period of hot weather too short, to cause much development of malaria.

The climate is in both provinces very healthy, and has been so from the earliest records, though, when the country was first settled, there was much scurvy.

Enteric fever is sometimes seen. Typhus has often been carried in emigrant ships, but has not spread, or at least has soon died out. Cholera has prevailed. Yellow fever dies out. Consumption is decidedly infrequent.

Acute pulmonary diseases used to be considered the prevalent complaints, but it is doubtful whether they are much more common than elsewhere.

Diseases of the Troops.

Years 1817–36 (20 years).—Admissions per 1000 of strength = 1097; deaths 16·1 (without violent deaths).

Years 1837–46 (10 years).—Yearly admissions per 1000 of strength, 982; average daily sick per 1000 of strength, 39·1; mortality (violent deaths excluded), 13; mortality with violent deaths, 17·42.

The mortality was made up in part of—fever, 2·13; lung disease, 7·44; stomach and bowels disease, 1·11; brain disease, 1·28. Nearly two-thirds of the fevers are returned as "common continued," probably enteric.

Venereal admissions, 117 per 1000.

Erysipelas was epidemic at Quebec, Montreal, and Toronto in 1841; at Montreal in 1842, from bad sanitary conditions.

The following table shows the mean of the later years:—

Years.	Loss of Strength per 1000.			Loss of Service per 1000.		
	By total Deaths.	By deaths from Disease.	By Invaliding.	Admissions.	Mean daily Sick.	Days in Hospital to each Sick Man.
1861–70 (10 years),	9·01	...	15·9	646·9	30·36	17·14
1871,	9·55	5·87	17·6	679·8	33·15	17·80

Influence of Age on Mortality.

Years.	Under 20.	20-24.	25-29.	30-34.	35-39.	40 and over.
1861-70 (10 years), .	3·47	6·01	9·80	11·13	17·66	20·23

These numbers show, what indeed is apparent in all the records, that Canada is a very healthy station.

The amount of phthisis was always smaller than on home service, and regiments of the Guards proceeding from London to Canada had on two occasions a marked diminution in phthisical disease.

In this respect, also, Canada contrasted formerly with the West Indies, but of late years the decline of phthisis in the West Indies has lessened the superiority of Canada.

The comparatively small amount of phthisis was remarkable, as the troops were at times very much crowded in barracks. Latterly they had the home allowance of space (600 cubic feet). In the later years phthisis declined considerably with improved barrack accommodation.

In the 20 years 1817-36 the annual admissions were 6·5, and the deaths 4·22, per 1000 of strength.

In the years 1859-65 the admissions from the whole tubercular class were 8·3, and the deaths were 1·67, per 1000 of strength.[1] It is curious to observe that this diminution was coincident with a similar change at home.[2] The acute lung affections, pneumonia and acute bronchitis, appear formerly to have been rather more prevalent in Canada than they were in later years.

The following table gives the mean and extremes for 8 years (1859-66):—

	Per 1000 of Strength. Admissions.	Deaths.
Pneumonia—Mean, . . .	12·24	0·8576
Highest, . . .	15·33	1·996
Lowest, . . .	7·91	0·411
Acute bronchitis—Mean, . .	42·67	0·309
Highest, . .	49·79	0·719
Lowest, . .	28·48	0·092
Average of the mean of both, .	27·45	0·5833

If this table is compared with the prevalence of these diseases at home, it appears that both pneumonia and acute bronchitis were rather more fatal at that time in Canada. Both together gave a mortality of ·868 per 1000 at home, and 1·166 per 1000 in Canada. The admissions from pneumonia were also higher, but those from acute bronchitis were one-third less than at home, showing that the common catarrhal affections were less frequent in Canada. On the whole, however, the influence of the severe climate and the exposure on guard in Canada produced less effect than might have been anticipated.

"Continued fevers" (probably enteric) almost yearly gave some mortality; the mean being about ·6 per 1000 of strength. This was actually more than

[1] Still the lung complaints were higher than they ought to have been. Sir William Muir (*Army Med. Reports*, vol. viii. p. 56), after detailing the measures taken by him to improve the barrack accommodation, says: "I cannot help thinking that the large number of men treated and invalided for chest disease, during the five years I have been on this command, bear a close relationship to this impure state of barrack air."

[2] In contrasting the consumptive invalidity at Gibraltar, Bermuda, and Canada, the Reporters of 1839 (*Army Med. Report*) remark that the returns "afford another interesting proof how little the tendency to consumption is increased either by intensity of cold or sudden atmospherical vicissitudes." See also the remarks on phthisis in India at a subsequent page.

on home service, and depended probably on the difficulties connected with drainage. A good dry system is the only plan which can be depended on in Canada.

The great healthiness of Canada in part probably depends on the fact, that the extreme cold in winter lessens or prevents decomposition of animal matter and the giving off of effluvia; hence, in spite of bad drainage and deficient water, there is no very great amount of fever. In the hot summer the life is an open-air one. Even in winter the dry cold permits a good deal of exercise to be taken.

The amount of drunkenness and delirium tremens in Canada used to be great. In 1863 no less than 9 out of 96 deaths, or nearly one-tenth, were caused by delirium tremens. Violent deaths also are usually large, drowning giving the largest proportion.

The sickness and mortality of Nova Scotia and Newfoundland are almost identical with Canada, and they are now included in the returns under the one head of "Dominion of Canada." Both stations have always been considered very healthy. There is some enteric fever at Halifax, and at both places there was formerly much drinking, but that is now less. In 1884 there were only 3 deaths from disease out of 1265 men—1 phthisis, 1 pneumonia, and 1 Bright's disease. In British Columbia, where there is a small garrison of 100 to 150, the health is also extremely good.

SECTION V.

AFRICAN STATIONS.

Sub-Section I.—St Helena.

Garrison, 200. In 1880 only 194. Civil population (in 1881), 5059.

Until comparatively recently this small island was garrisoned by a local corps (St Helena regiment), which has now been disbanded.

The island has always been healthy; seated in the trade-winds, there is a tolerably constant breeze from south-east. The average mortality in the years 1859–66 was 9·75, or without violent deaths, 7·85. In 1867 the mortality from disease was only 5·24. In 1875 almost the same, viz., 5·41. There is very little malarious disease (about 50 to 60 admissions per 1000 of strength), but there have frequently been a good many cases of "continued fever," and dysentery and diarrhœa are usual diseases. Formerly there appears to have been much phthisis, but this is now much less, giving another instance of the decline of this disease, as in so many other stations.

In the years 1837–46, the admissions from tubercular diseases averaged 21 per 1000 per annum, and the deaths 5·45. In the years 1859–66 the admissions from tubercular diseases were 6·6, and the deaths 1·66 per 1000. In 1867 there were no admissions. The health of the troops would have been even better if the causes of the continued fever and dysentery could have been discovered and removed, and if the amount of drunkenness had been less. The returns from St Helena are now combined with those from the Cape of Good Hope.

Sub-Section II.—West Coast of Africa.[1]

The principal stations are Sierra Leone and Cape Coast Castle.

The station of Gambia has now been given up, and troops are no longer

[1] For a very good account of the topography of the Gold Coast, see Dr R. Clarke's paper in the *Transactions Epid. Society*, vol. i.

stationed regularly at Lagos (500 miles from Cape Coast Castle, and occupied in 1861). In 1875 Sierra Leone, Cape Coast, and Accra were occupied, and Elmina for a short time, and since then the two first stations have been alone garrisoned. No white troops are employed, except during war-time, as in the Ashanti campaign of 1873.

Sierra Leone.

Strength of garrison, 300 to 500 black troops, with a few European officers and non-commissioned officers. Civil population (in 1872), 37,089. Hot season from May to the middle of November; Harmattan wind in December; soil, red sandstone and clay, very ferruginous. There are extensive mangrove swamps to N. and S. Water very pure. The spring in the barrack square contains only 3 to 4 grains per gallon of solids.

This station had formerly the reputation of the most unhealthy station of the army. Nor was this undeserved.

From 1817 to 1837 (20 years) there were yearly among the troops—

Admissions, . . .	2978 per 1000.
Deaths, ...	483 ,,

At the same time, about 17 per cent. of the whole white population died annually.

The chief diseases were malarious fevers, which caused much sickness, but no great mortality; and yellow fever, which caused an immense mortality. Dysentery, chiefly scorbutic, was also very fatal.

The causes of this great mortality were simple enough. The station was looked upon as a place of punishment, and disorderly men, men sentenced for crimes, or whom it was wished to get rid of, were draughted to Sierra Leone. They were there very much overcrowded in barracks, which were placed in the lower part of the town. They were fed largely on salt meat; and being for the most part men of desperate character, and without hope, they were highly intemperate, and led, in all ways, lives of the utmost disorder. They considered themselves, in fact, under sentence of death, and did their best to rapidly carry out the sentence.

Eventually, all the white troops were removed, and the place has since been garrisoned by one of the West Indian regiments. Of late years, the total white population of Sierra Leone (civil and military) has not been more than from 100 to 200 persons.

The great sickness and mortality being attributable, as in so many other cases, chiefly to local causes and individual faults, of late years Europeans have been comparatively healthy; although from time to time fatal epidemics of yellow fever occur. They are, however, less frequent and less fatal than formerly. The position of the barracks has been altered, and the food is much better. One measure which is supposed to have improved the health of the place, is allowing a species of grass (Bahama grass) to grow in the streets. The occupiers of the adjacent houses are obliged to keep it cut short, and in good order.

During the four years 1863–66 there died 8 white non-commissioned officers, in the whole command of the West Coast, out of an average strength of 25; or at an annual rate of 80 per 1000 of strength. Three of the 8 deaths were from liver disease, two from delirium tremens, two from fevers, and one from dysentery. In 1867 two sergeants died, out of 15 white men—one from apoplexy, one from delirium tremens.

Among the black troops serving in Sierra Leone and the Gold Coast, the

returns of the ten years 1861–70 give 1283 admissions and 22·49 deaths per 1000. In 1871 the deaths were 15·63 per 1000 from disease. In ten years (1870–79) the admissions were 1640·5 and the deaths 25·07 per 1000. 1873 was the year of the last Ashanti war. In 1880 the admissions were 1565·7 and the deaths 22·47, of which 20·86 were from disease. These numbers are for the whole West African command. Among the causes of death, tubercular diseases hold the first place, amounting to 7·05 per 1000 of strength. In 1862 phthisis amounted to no less than 12·6 per 1000 of strength, and constituted 43·7 per cent. of all deaths from disease. There were also 9·46 per 1000 of strength deaths from pneumonia. In 1863 the deaths from phthisis were 9·3 per 1000 of strength, and made up 36·3 per cent. of the total deaths. In 1867 the tubercular deaths per 1000 of strength were 17·71 in Sierra Leone, 15·87 at the Gambia, and 12·58 at the Gold Coast and Lagos together. In 1880 the total rate for the command was 11·23 per 1000. It seems clear, indeed, that in all the stations of the West India corps (black troops), the amount of phthisis is great; in fact, the state of health generally of these regiments requires looking into, as in the West Indies.

In 1862 there were only five cases of intermittent, and eighteen of remittent fever among 317 negroes. In 1880 the number was 404 out of 623; in 1884, 163 out of 539.

In 1861 some of the troops from Sierra Leone and the Gambia were employed up the Gambia against the Mandingoes, and also against the chiefs of Quiat. In 1863 and 1864, and again in 1873, Ashanti wars prevailed. All these wars added to the sickness and mortality, so that these years are not fair examples of the influence of the climate.

Gambia.

No troops have been quartered here of late years, and it has been in contemplation to abandon the station. It is much more malarious than any of the others. The drinking water is bad; all barrack and sewage arrangements are imperfect. Yellow fever from time to time is very destructive. In 1859 two out of four European sergeants, and in 1860 three medical officers died of yellow fever. Among the black troops, in 1859–65, the admissions were 1169·8 and the deaths 29·97 per 1000 of strength.

As at Sierra Leone, phthisis and other diseases of the lungs caused a large mortality among the negroes. In 1861 phthisis gave five deaths out of a strength of 421, or at the rate of 11·6 per 1000 strength; and pneumonia gave four deaths, and acute bronchitis three, or (together) at the rate of 16·24 per 1000 of strength. Phthisis, pneumonia, and bronchitis gave nearly 60 per cent. of all deaths from disease. This was higher than in previous years; but in 1862 phthisis gave 14·35 deaths per 1000 of strength, and constituted 75 per cent. of the whole number of deaths. There was, however, no pneumonia or bronchitis in that year. In 1856 the tubercular class gave 9·53 deaths per 1000. In 1863, however, there were no deaths from phthisis. Although the period of observation is short, it can hardly be doubted that here, as elsewhere in the stations occupied by the West Indian regiments, some causes influencing the lungs prejudicially are everywhere in action. These are probably to be found in conditions arising from bad ventilation of the barracks.

Among the few white residents at the Gambia, diarrhœa, dysentery, and dyspepsia appear to be common. These, in part, arise from the bad water;

in part from dietetic errors (especially excess in quantity), and want of exercise and attention to ordinary hygienic rules.

Cape Coast Castle (Gold Coast).

Garrison, 300 to 400 (black troops).

This station has always been considered the most healthy of the three principal places. It is not so malarious as even Sierra Leone, and much less so than the Gambia, and has been much less frequently attacked with yellow fever. Dysentery and dyspepsia are common diseases among the white residents. Among the black troops the prevalence of phthisis, pneumonia, and bronchitis is marked, though less so, perhaps, than at the other two stations.

One peculiarity of the station was the prevalence of dracunculus. This was much less common at Sierra Leone and at the Gambia. It appears to have lessened considerably in later years, but there is no definite information now to be obtained from the *A.M.D. Reports.*

Hygiene on the West Coast.

There is no doubt that attention to hygienic rules will do much to lessen the sickness and mortality of this dreaded climate. In fact, here as elsewhere, men have been contented to lay their own misdeeds on the climate. Malaria has, of course, to be met by the constant use of quinine during the whole period of service. The other rules are summed up in the following quotation from Dr Robert Clarke's paper,[1] and when we reflect that this extract expresses the opinion of a most competent judge on the effect of climate, we must allow that, not only for the West Coast, but for the West Indies, and for India, Dr Clarke's opinions on the exaggeration of the effect of the sun's rays and exposure to night air, and his statement of the necessity of exercise, are full of instruction :—

"Good health may generally be enjoyed by judicious attention to a few simple rules. In the foremost rank should be put *temperance*, with regular and industrious habits. European residents on the Gold Coast are too often satisfied with wearing apparel suited to the climate, overlooking the fact that exercise in the open air is just as necessary to preserve health there as it is in Europe. Many of them likewise entertain an impression that the sun's rays are hurtful, whereas in nine cases out of ten the mischief is done, not by the sun's rays, but by habits of *personal economy.* Feeling sadly the wearisome sameness of life on this part of the coast, recourse is too frequently had to stimulants, instead of resorting to inexhausting employments, the only safe and effectual remedy against an evil fraught with such lamentable consequences. Europeans also bestow too little attention on ventilation, far more harm being done by close and impure air during the night than is ever brought about by exposure to the night air.

"Much of the suffering is occasioned by over-feeding."[2]

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[1] *Trans. of the Epidem. Soc.*, vol. i. pp. 123, 124.

[2] Considerable interest in this part of the work was roused by the occurrence of the Ashanti war of 1873, for an admirable account of which see the *Army Medical Reports*, vol. xv., where Sir Anthony D. Home gives a full medical history of the operations carried on. The excellent hygienic arrangements enabled the arduous work of the expedition to be accomplished with a comparatively small loss. But the few casualties in action compared with the deaths by disease show by contrast how much more deadly were the forces of nature than those of the enemy. 26 officers died, of whom only five were killed or died of wounds; 13 men were killed (white troops), whilst 40 died of disease; of the West Indian troops (black) only one was killed, whilst 41 died of disease. For analysis of soil of Gold Coast, see *Army Med. Reports*, vol. xiv. p. 264; and for some account of the drinking water, see papers by Dr J. D. Fleming in vols. xiv. and xv.

SUB-SECTION III.—CAPE OF GOOD HOPE.

Garrison, about 3000 men.

The chief stations are Cape Town (about 45,000 inhabitants), Graham's-Town, King William's Town, Port Elizabeth, Algoa Bay, and several small frontier stations. In Natal there is also a small force. The climate is almost everywhere good; the temperature is neither extreme nor very variable; the movement of air is considerable.

At Cape Town the mean annual temperature is 67°, with a mean annual range of about 38°.

Years.	Total Deaths.	Admissions.	Mean daily Sick.	Days in Hospital to each Sick Man.
1860–69 (10 years), .	10·87	973	50·24	18·83
1870–77 (8 years),[1] .	9·72	906	43·85	17·88

The statistics of later years are complicated by the casualties of war, including killed and wounded in action and a great excess of fever. Eliminating these, we have the following ratios per 1000 :—

Years.	Total Admissions.	Wounds and Injuries.	Admissions for Disease only.	Continued Fever.	Paroxysmal Fever.	Admissions for Disease, excluding Fevers.
1870–77 (8 years of peace), . .	906	131	775	39	28	708
1878–80 (3 years of war), . .	900	103	797	159	38	600
1879–83 (5 years),	825	95	730	141	48	541

Deaths per 1000 *of Strength.*

Years.	Total.	Wounds and Injuries and Killed in Action.	Disease only.	Continued Fever.	Paroxysmal Fever.	Deaths from Disease, excluding Fevers.
1870–77 (8 years),	9·72	1·94	7·78	0·50	0·24	7·04
1878–80 (3 years),	50·43	28·98	21·45	11·16	1·13	9·18
1879–83 (5 years),	53·71	34·56	19·15	2·53	—	16·62

As regards the admissions, it is clear that the diminution which might have been expected in consequence of sanitary improvements was chiefly arrested by the great number of cases of continued fever which occurred during the period of hostilities. In times of peace there is but little fever, and a small and decreasing mortality. Thus in 1856–66 the death-rate was 1·25 per 1000, in 1870–77 only 0·50,—whilst in 1878–80 it was no less than 11·16; in all these cases the deaths are almost invariably enteric. Paroxysmal fevers arising in the station itself are very uncommon, the worst year in the period 1870–77 being 1874, when these diseases appeared among troops from the Mauritius, where it had undoubtedly been contracted. During the period of hostilities there was an increase both in admissions and deaths from that cause. Although the net admissions (after eliminating wounds and injuries and fevers) are less in the later period (1878–80) than in the earlier (1870–77), as shown in the preceding table, yet the death-rate

[1] Including the detachment at St Helena.

is higher. This is almost entirely due to diseases of the digestive system, mostly dysentery and diarrhœa. These were more common formerly than they are now in ordinary years; in many cases, especially in the small frontier stations, they were clearly owing to bad water.

Ophthalmia has prevailed rather largely, especially in some years; there is a good deal of dust in many parts of the colony, and it has been attributed to this; the disease is probably the specific ophthalmia (grey granulations), and is propagated by contagion. Whether it had its origin in any catarrhal condition produced by the wind and dust, and then became contagious, is one of those moot points which cannot yet be answered.

The Cape has always been noted for the numerous cases of muscular rheumatism. Articular rheumatism is not particularly common. There is also much cardiac disease. The prevalence of this affection has been attributed to the exposure and rapid marches in hill districts during the Kaffir wars. In 1863 there was, however, less rheumatism than usual.

Taking the years 1859–66 as expressing tolerably fairly the effect, *per se*, of the station, we find that the whole colony gave 18·3 admissions and 1·90 deaths per 1000 of strength from diseases of the circulatory organs. In 1869–77 the admissions were 13·5 and the deaths 1·47; in 1878–80 they were 20·3 and 1·25 respectively; in 1879-83 the admissions were 18·6 and the deaths 0·65; in 1884 admissions 12, deaths 0·32.

Dr Lawson[1] contributed a valuable paper on this subject. He found the death-rate from diseases of the organs of circulation (mean of seven years, 1859–65) at 1·91 per 1000 of strength. This was higher than at any other foreign station, as will be seen from the table copied by Dr Lawson.

Mortality from Diseases of the Circulatory Organs.

	Ratio per 1000 of Strength.		Ratio per 1000 of Strength.		Ratio per 1000 of Strength.
Cape of Good Hope,	1·91	Bombay,	0·80	Malta,	0·53
New Zealand,	1·18	Bengal,	0·86	Gibraltar,	0·70
Australia,	1·72	South China,	1·16	Bermuda,	1·25
Mauritius,	0·53	West Indies,	1·02	Nova Scotia,	0·84
St Helena,	0·31	Jamaica,	0·85	Canada,	1·19
Ceylon,	1·11	Ionia,	0·84	Home,	0·93
Madras,	1·12				

This table shows an extreme diversity, hardly to be reconciled with differences of climate or duties. In the years 1869–74 the death-rate was 1·68, and was exceeded by that of the Mauritius, 2·29, and that of Madras, 1·99. In 1875 the rate at the Cape was only 1·45, while Ceylon showed 3·87, Bermuda 2·63, and Madras 2·05; Mauritius returning no death. In the eight years 1870–77 the rate at the Cape was 1·62; and in the years 1878–80 it was 1·25; in 1879–83 it was 0·65, and in 1884 only 0·32, there being only 1 death out of 3157 of strength.

Scurvy formerly prevailed much at the Cape, particularly in the Kaffir wars, and may have had something to do with the prevalence of dysentery.

Venereal diseases were very common. The average admissions from "enthetic" diseases in 1859–66 were 248·5, and in 1867 they were 438·3 per 1000 of strength in the whole colony. In Cape Town alone, where facilities for promiscuous intercourse are greater, they were even more numerous.[2] Much diminution has taken place in recent years. In the ten

[1] *Army Medical Reports*, vol. v. p. 338.
[2] *Army Med. Depart. Reports*, vol. viii. p. 548.

years 1871–80 the ratio for syphilis, both primary and secondary, was only 102, and for gonorrhœa 80; in 1879–83 the admissions were, for primary syphilis, 89, secondary 24·4; for gonorrhœa 74·1.

The Cape has always been considered a kind of sanitarium for India. Its coolness and the rapid movement of the air, the brightness and clearness of the atmosphere, and the freedom from malaria, probably cause its salubrity. It has been supposed that it might be well to send troops to the Cape for two or three years before sending them on to India. This plan has never been perfectly tried; but in the case of regiments sent on hurriedly to India on emergency it has been said that the men did not bear the Indian climate well. Probably they were placed under unfavourable conditions, and the question is still uncertain.

As a convalescent place for troops who have been quartered in a malarious district it is excellent.[1]

SECTION VI.

MAURITIUS.

Garrison, about 300 to 500 men. Civil population (in 1879), 359,988.

Mauritius in the eastern has been often compared with Jamaica in the western seas. The geographical position as respects the equator is not very dissimilar; the mean annual temperature (80° Fahr.) is almost the same; the fluctuations and undulations are more considerable, but still are not excessive; the humidity of air is nearly the same, or perhaps a little less; the rainfall (66 to 76 inches) is almost the same; and the physical formation is really not very dissimilar. Yet, with all these points of similarity in climatic conditions, the diseases are very different.

Malarious fever was formerly not nearly so frequent as in Jamaica, and true yellow fever is quite unknown; Mauritius, therefore, has never shown those epochs of great mortality which the West Indies have had. Hepatic diseases, on the other hand, which are so uncommon in the West Indies, are very common in the Mauritius. For example, in 1859 there were 47 cases of acute and chronic hepatitis in 1254 men, while in Jamaica there was one case out of 807 men. In 1860 there were 31 admissions from acute hepatitis out of 1886 men; in Jamaica there was not a single case. In 1862 there were 12 cases of acute, 11 of chronic hepatitis, and 72 cases of hepatic congestion, out of 2049 men; in Jamaica, in the same year, there was only 1 case of acute hepatitis out of 702 men. This has always been marked; is it owing to an error in diagnosis, or to differences in diet? It can scarcely be attributed to any difference in climate. In 1863 the difference was less marked, but was still evident. In later years, however, there has been considerable diminution: in 1872 there were only 4 cases of hepatitis, and in 1873 only 2. Since that year no detailed statistics have been published, but it is mentioned incidentally that there were 3 cases in 1880, out of a strength of 353, and in 1884 there were 8 cases out of 363 men.

In 1866–67 a very severe epidemic fever prevailed in the Mauritius, which offers many points of interest. As already noted, the Mauritius has till lately been considered to be comparatively free from malaria. All the older writers state this, and it is apparent from all the statistical returns. Deputy Inspector-General Dr Francis Reid, in a report[2] in 1867, mentions that he had served ten years in the Mauritius, and had looked over the records of the troops for twenty-four years. He found some records of intermittents,

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[1] See effect on the 59th regiment, in the *Army Medical Report* for 1859, p. 99.
[2] *Letter to the Director-General*, Feb. 1867.

but he traced all these to foreign sources, viz., troops coming from India, China, or Ceylon, and presenting cases of relapses.

For the first time, in the latter months of 1866 and the commencement of 1867, malarious fevers of undoubted local growth appeared on the western side of the island.

The causes of this development were traced by Dr Reid, and also by Surgeon-Major Small and Assistant-Surgeon W. H. T. Power, in some very careful reports.[1] During some years a large amount of forest land had been cleared, and there had been much upturning of the soil; coincidently the rainfall lessened, and the rivers became far less in volume. At the same time, there was a large increase of population; a great defilement of the ground in the neighbourhood of villages and towns, so that in various parts of the island there was a constant drainage down of filth of all kinds (vegetable and animal) into a loose soil of slight depth, resting on impermeable rock, which forms a great deal of the western seaboard. In 1866–67 there occurred an unusually hot season, and again a deficient rainfall. This seems to have brought into active operation the conditions which had been gradually increasing in intensity for some years. The development of the malaria was not so much on the regular marshy ground as on the loose contaminated soil already noticed.

That the fever which in 1866–67 became so general was of malarious type, is proved by a large amount of evidence on the spot from both military and civil practitioners, and from the fact that many soldiers returned to England and had at home relapses of decided paroxysmal fevers. Dr Maclean also stated that he had seldom seen spleens so enlarged as among the invalids from this fever who arrived at Netley.

But in some respects this fever presented characters different from common paroxysmal fevers. There was no very great mortality among the troops, but it was excessively fatal among the inhabitants of Port Louis and many other towns and villages. It also lasted for many months, and was attended in many cases with symptoms not common in ordinary paroxysmal fevers, viz., with yellowness of the skin and with decided relapses, closely resembling in these respects the common relapsing fever. Mixed up with it also was decided enteric fever. The question whether the great bulk of the epidemic was a purely paroxysmal or malarious fever, with an independent subordinate outbreak of enteric fever, or whether it was a composite affection like the "typho-malarial fever" of the American war,[2] or was mixed up with the contagious "Indian jail fever" imported by coolies, is not a matter very easy to decide. The officers best qualified to judge (Drs Reid, Small, and Power) looked upon it as a purely malarious disease, and expressed themselves very strongly on this point.[3]

This much seems certain, that in various parts of the island the loose, porous, shallow soil had been gradually becoming more and more impure with vegetable matters, and in some cases with animal excreta; that there had been a gradual diminution of the subsoil water, and that this reached its minimum in 1866, when the rains failed, and the hot season was prolonged. There coincided, then, an unusual impurity of soil, lowered subsoil water, consequent increased access of air, and heightened temperature.

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[1] *Annual Report on the District Prisons Hospitals* (in 1867, Mauritius, 1868). On the Malarial Epidemic Fever of the Mauritius, *Army Med. Depart. Report*, vol. viii. p. 442.

[2] As described by Woodward, *Camp Diseases of the United States Armies*, by J. J. Woodward, M.D., Philadelphia, 1863, p. 77.

[3] The two latter gentlemen say, *op. cit.*, p. 453: "It was entirely of malarious origin, and in every form, we might say, perfectly curable by administration of quinine in large doses." These observers entirely deny that it had any contagious properties.

Under these conditions, a usually non-malarious soil gave rise to an epidemic fever, which was characterised (chiefly at any rate) by the symptoms referred to the action of marsh miasmata, and was curable by quinine. The admissions for paroxysmal fevers alone were, in 1875, 585·5 per 1000, and in 1869–75 (five years) 722·3 per 1000 as a mean. In later years the type has been distinctly paroxysmal, the large majority of cases being returned as *ague.* The mean admissions per 1000 for six years, 1875–80, were 970, with a maximum of 1557 in 1879; in the five years 1879–83 they were 1167; and in 1884, 1358.

In the Mauritius, as in Jamaica, a "continued fever" is not uncommon; this is now being returned in part as enteric.[1] It has occasionally been imported. There are fevers vaguely named "bilious remittent," "Bombay fever," "coolie fever," &c. The last term denotes the communicable fever so common in the jails in the Bengal Presidency. It prevailed in the jails in the Mauritius in 1863 and 1864, among the Hindoos. The "Bombay fever" is probably enteric. Dysentery and diarrhœa have largely prevailed, but are now becoming less frequent. In this respect Jamaica now contrasts very favourably with the Mauritius; thus, in 1860, there were altogether 213 admissions per 1000 of dysentery and diarrhœa, and 6·8 deaths per 1000; in Jamaica, in the same year, there was not a single admission from dysentery, and only 19 from diarrhœa, among 594 men, and no death. Cholera has prevailed five times, first in 1819; not afterwards till 1854; then again in 1856, 1859, and 1861. (It appears to have been imported in all these cases.) Formerly there was a large mortality from lung diseases; now, as in Jamaica, this entry is much less, not more than half that of former days. The deaths from phthisis per 1000 of strength were, in 1860, 0·521; in 1861, 1·03; in 1862, 1·94 (but in this year 11 men were invalided for phthisis); and in 1863, 2; in 1875 no death was recorded. Venereal (enthetic) diseases formerly gave about 110 to 130 admissions per 1000 of strength, but they are now greatly diminished. Ophthalmia prevails moderately; to nothing like the same extent as at the Cape.

In 1873 (the last year of detailed statistics) there were 8 admissions for diarrhœa and none for dysentery in Jamaica; in Mauritius there were 29 for diarrhœa and 16 for dysentery, and 2 deaths, out of a strength of 441.

Per 1000 *of Strength.*

Years.	Loss of Strength.			Loss of Service.		
	Deaths (all Causes).	Deaths from Disease.	Invaliding.	Admissions.	Mean daily Sick.	Days in Hospital to each Sick Man.
1817–36, .	30·50	...	...	1249	68	20
1861–70 (10 years), .	20·17	...	...	1056·5	.. .	...
1865–74 (10 years), .	18·97	...	44·15	1419·4	53·58	13·76
1875–80 (6 years), .	17·89	...	48·03	2181·7	70·36	11·65
1879–83 (5 years), .	14·75	13·65	54·61	2378·5	96·01	14·76
1884, .	22·03	22·03	46·83	2294·8	95·73	15·24

[1] Dr Reid had no doubt of the frequent occurrence of enteric fever for many years. He mentioned an interesting fact, viz., that patients with true enteric fever were also affected with the malarious epidemic fever; this latter was, however, easily curable by quinine, but the enteric fever, which was also present, was quite unaffected.

SECTION VII.

CEYLON.[1]

Garrison, 800 to 1000 white troops; and about 100 gun-lasears (blaek). Population, 2,758,166 (in 1881), inelnding about 5000 Europeans. The stations for the white troops are ehiefly Galle, Colombo, Kandy, and Trineomalee, with a eonvaleseent station at Newera Ellia (6200 feet above sea-level). The blaek troops are more seattered, at Badulla, Pultan, Jaffna, &e.

Geology.—A eonsiderable part of the island is eomposed of granite, gneiss, and hornblende granite roeks; these have beeome greatly weathered and deeomposed, and form masses of a eonglomerate ealled "eabook," whieh is elayey, like the laterite of India, and is used for building. The soil is derived from the débris of the granite; it is said to absorb and retain water eagerly. In some parts, as at Kandy, there is erystalline limestone.

Climate.—This differs, of eourse, exeeedingly at different elevations. At Colombo, sea-level, the elimate is warm, equable, and limited. Mean annual temperature about 81°. Mean temperature—April, 82°·70; January, 78°·19; amplitude of the yearly fluetuation = 4°·51. April and May are the hottest months; January and Deeember the eoldest. Amonnt of rain about 74 inehes; the greatest amount falls in May with the S.W. monsoon (about 13 to 14 inehes); and again in Oetober and November with the N.E. monsoon (about 10 to 12 inehes) in eaeh month. Rain, however, falls in every month, the smallest amount being in February and Mareh. The heaviest yearly fall ever noted was 120 inehes. The relative humidity is about 80 per eent. of saturation. The S.W. monsoon blows from May to September, and the N.E. monsoon during the remainder of the year, being unsteady and rather diverted from its eourse (long-shore wind) in February and Mareh. The mean horizontal movement during the year 1872 was 125 miles; in 1870 it was 139 miles, or rather under 6 miles an hour.

At Kandy (72 miles from Colombo, 1676 feet above sea-level), the mean temperature is less, 3° to 5°; the air is still absolutely humid, though relatively rather dry. At 9.30 A.M. the mean annual dew-point is 70°·4, and at 3·30 P.M. it is 71°·54. This eorresponds to 8·11 and 8·42 grains in a eubie foot of air; as the mean temperature at these times is 76°·37 and 79°·27, the mean annual relative humidity of the air at 9.30 A.M. and 3·30 P.M. is 71 and 63 per eent. of saturation. The heat is oppressive, as Kandy lies in a hollow, as in the bottom of a cup.

At Newera Ellia (48 miles from Kandy, 6210 feet high) is a large table-land, where, sinee 1828, some Europeans have been stationed; the elimate is European, and at times wintry; the thermometer has been as low as 29°, and white frosts may oeeur in the early morning in the eoldest months. The mean annual temperature is about 59°.[2]

In the dry season (January to May) the thermometer's daily range is exeessive; the thermometer may stand at 29° at daybreak, and at 8 A.M. reaeh 62°; at mid-day it will mark 70° to 74°, and then fall to 50° at dark. In one day the range has been from 27° to 74° = 47°. The air is very dry, the differenee between the dry and wet bulbs being sometimes 15°. Assuming the dry bulb to mark 70°, this will give a relative humidity of only 38 per eent. of

[1] For a full account, see Sir E. Tennent's *Ceylon.*

[2] Many of these facts are from an excellent Report by Assistant-Surgeon R. A. Allan, as well as from Sir E. Tennent's book.

saturation; the barometer stands at about 24·25 inches. Although the diurnal range of temperature is thus so great, it is equable from day to day.

Such a climate, with its bright sun and rarefied air, an almost constant breeze, and an immense evaporating force, seems to give us, at this period, the very beau ideal of a mountain climate.

In the wet season (May or June to November) all these conditions are reversed. The mean thermometer of twenty-four hours is about 59°, and the range is only from 56° at daybreak to 62° at mid-day; during the height of the monsoon there are about 30 inches of rainfall, and sometimes as much as 70; the air is often almost saturated. The mean of three years (1870-72) gives no less than 94½ inches.[1]

Two more striking climatic differences than between January and June can hardly be conceived, yet it is said Newera Ellia is equally healthy in the wet as in the dry season; the human frame seems to accommodate itself to these great vicissitudes without difficulty. The most unhealthy times are at the changes of the monsoons.

Although there is some moist and even marshy ground near the station, ague is not common, though it is seen; the temperature is too low in the dry season, and the fall of rain too great in the wet. Enteric fever is seen, and may be combined with periodic fever.[2] It is said that dyspepsia, hepatic affections, and nervous affections, are much benefited: phthisis is so to some extent, but, it would appear, scarcely so much as European experience would have led us to expect; rheumatism does not do well, nor, it is said, chronic dysentery; but it would be very desirable to test this point, as well as that of the influence on phthisis, carefully. The so-called "hill-diarrhœa" of India prevailed in 1865, though before this it was unknown. Dysentery has sometimes prevailed, and is caused in some cases by bad water (Massy).

The soil of Newera Ellia is chiefly decomposed gneiss; it is described by Dr Massy as being as hygroscopic as a sponge; the contents of cesspools easily traverse it, and the removal of excreta demands great care.

The neighbouring Horton Hills are said to be even better than Newera Ellia itself. Probably in the whole of Hindustan a better sanitary station does not exist. It is inferior, if it be inferior, only to the Neilgherries and one or two of the best Himalayan stations.

Sickness and Mortality[3] *of Europeans per* 1000 *of Strength.*

Years.	Deaths.	Admissions.	Mean daily Sick.	Duration of Sickness.
1860–69 (10 years), . .	23·75	1424·9	66·52	16·6 days
1869–74 (6 years), . .	17·72	1112·6	...	...
1875–80 (6 years), . .	16·45	976·4	52·86	20·00
1879–83 (5 years), . .	16·23[4]	1249·3	62·69	18·38
1884, ...	11·17[5]	1198·0	67·49	20·56

[1] Since 1873 all meteorological information about Ceylon has been dropped out of the *Army Medical Reports*.

[2] Massy, in *Army Med. Reports*, vol. viii. p. 499.

[3] In 1876 the death-rate was only 7·43, but this was exceptional; in 1880 it was 25, the great excess being due to dysentery in the Colombo garrison.

[4] Only 13·5 from disease.

[5] Only 9·13 from disease.

Influence of Age on Mortality.

Years.	Under 20 years.	20 and under 25.	25 and under 30.	30 and under 35.	35 and under 40.	40 and over.
1864–73, ...	·7	15·89	28·81	26·50	50·25	173·91
1874–83, ...	3·46	10·68	10·61	13·42	24·14	44·94

Among the black troops, now reduced to about 100 altogether, in Ceylon (1860–69) the admissions averaged 1011, and the deaths 15·17, per 1000 of strength. In 1870 the total mortality was 9·44 (and, in 1880, 11·63) per 1000. The chief causes of admissions were paroxysmal fevers, and of deaths cholera, dysentery, and paroxysmal fevers. "Continued fever" also figures among the returns, but was less common in the later years. The average number constantly sick was about 32, and the duration of the cases 10 or 11 days.

In Ceylon, therefore, the black troops were healthier than the white, contrasting in this remarkably with the West Indies.

In conclusion, it may be said that much sanitary work still remains to be done in Ceylon before the state of the white troops can be considered satisfactory.

SECTION VIII.

INDIA.

About 55,000 Europeans are now (1884) quartered in India, and there is in addition a large native army. In this place the Europeans will be chiefly referred to, as it would require a large work to consider properly the health of the native troops.

The 55,000 Europeans are thus distributed :—About 34,000 are serving in the Bengal Presidency, which includes Bengal proper, the North-West Provinces, the Panjāb, and the Trans-Indus stations. About 10,000 to 11,000 are serving in the Madras Presidency, which also garrisons some parts of the coast of Burmah, and sends detachments of native troops to the Straits of Malacca. About the same number are serving in the Bombay Presidency.[1] The troops consist of all arms.

These men are serving in a country which includes nearly 28° of lat. and 33° of long., and in which the British possessions amount to 1,470,207 square miles, and the population to 253,000,000. Stretching from within 8° of the equator to 13° beyond the line of the tropics, and embracing countries of every elevation, the climate of Hindustan presents almost every variety; and the troops serving in it, and moving from place to place, are in turn exposed to remarkable differences of temperature, degrees of atmospheric humidity, pressure of air, and kind and force of wind, &c.

Watered by great rivers, which have brought down from the high lands vast deposits in the course of ages, a considerable portion of the surface of the extensive plains is formed by alluvial deposit, which, under the heat of the sun, renders vast districts more or less malarious; and there are certain parts of the country where the development of malaria is probably as intense as in any part of the world. A population, in some places thickly clustered, in others greatly scattered, formed of many races and speaking

[1] For brevity, it is customary to speak of serving in Bengal, Bombay, or Madras, when speaking of the presidency, so that these names are sometimes applied to the cities, sometimes to the presidencies; but a little care will always distinguish which is meant.

many tongues, and with remarkably diverse customs, inhabits the country, and indirectly affects very greatly the health of the Europeans.

Cantoned over this country, the soldiers are also subjected to the special influences of their barrack life, and to the peculiar habits which tropical service produces.

We can divide the causes which act on the European force into four subsections—

1. The country and climate.
2. The diseases of the natives.
3. The special hygienic conditions under which the soldier is placed.
4. The service and the individual habits of the soldier.

Sub-Section I.—The Country and Climate.

The geological structure and the meteorological conditions are, of course, extremely various, and it is impossible to do more than glance at a few of the chief points.

1. *Soil.*[1]—There is almost every variety of geological structure. In the north-west, the vast chain of the Himalayas is composed of high peaks of granite and gneiss; while lower down is gneiss and slate, and then sandstone and diluvial detritus. Stretching from Cape Comorin almost to Guzerat, come the great Western Ghauts, formed chiefly of granite, with volcanic rocks around; and then, stretching from these, come the Vindhya and Satpūra Mountains, which are chiefly volcanic, and inclose the two great basins of the Taptī and Nerbudda rivers. Joining on to the Vindhya come the Aravalli Hills, stretching towards Delhi, and having as their highest point Mount Abū, which is probably destined to become the great health resort of that part of India.

On the east side, the lower chain of the Eastern Ghauts slopes into the tableland of the Deccan; and at the junction of the Eastern and Western Ghauts come the Neilgherry Hills, from 8000 to 9000 feet above sea-level, and formed of granite, syenite, hornblende, and gneiss. But to enumerate all the Indian mountains would be impossible.

Speaking in very general terms, the soil of many of the plains may be classed under four great headings:—

(*a*) Alluvial soil, brought down by the great rivers Ganges, Indus, Brahmapūtra, rivers of Nerbudda, Guzerat, &c. It is supposed that about one-third of all Hindustan is composed of this alluvium, which is chiefly siliceous, with some alumina and iron. At points it is very stiff with clay—as in some parts of the Panjāb, in Scinde, and in some portion of Lower Bengal. Underneath the alluvial soil lies, in many places, the so-called clayey laterite. Many of the stations in Bengal are placed on alluvial soil.

This alluvial soil, especially when, not far from the surface, clayey laterite is found, is often malarious; sometimes it is moist only a foot or two from the surface; and, if not covered by vegetation, is extremely hot.

As a rule, troops should not be located on it. Whatever be done to the spot itself—and much good may be done by efficient draining—the influences of the surrounding country cannot be obviated. Europeans can never be entirely free from the influences of malaria. There is but one perfect remedy; to lessen the force in the plains to the smallest number consistent with military conditions, and to place the rest of the men on the higher lands.

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[1] See Carter's "Summary of the Geology of India," in the *Journal of the Bombay Asiatic Society's Transactions*, 1853.

Somewhat different from the alluvial is the soil of certain districts, such as the vast Runn of Cutch, which have been the beds of inland seas, and now form immense level marshy tracts, which are extremely malarious. The Runn of Cutch contains 7000 square miles of such country.

(*b*) The so-called "regur," or "cotton soil," formed by disintegrated basalt and trap, stretches down from Bundelcund nearly to the south of the peninsula, and spreads over the table-land of Mysore, and is common in the Deccan. It is often, but not always, dark in colour. It contains little vegetable organic matter (1·5 to 2·5 per cent.), and is chiefly made up of sand (70 to 80 per cent.), carbonate of lime (10 to 20 per cent.), and a little alumina. It is very absorbent of water, and is generally thought unhealthy. It is not so malarious as the alluvium, but attacks of cholera have been supposed to be particularly frequent over this soil.

(*c*) Red soil from disintegration of granite. This is sometimes loamy, at other times clayey, especially where felspar is abundant. The clay is often very stiff.

(*d*) Calcareous and other soils scattered over the surface, or lying beneath the alluvium or cotton soil. There are, in many parts of India, large masses of calcareous (carbonate of lime) conglomerate, which is called kankar. It is much used in Bengal for pavements, footpaths, and roads generally.

In Behar, and some other places, the soil contains large quantities of nitre, and many of the sand plains are largely impregnated with salts.

2. *Temperature.*—There is an immense variety of temperature. Towards the south, and on the sea-coast, the climate is often equable and uniform. The amplitudes of the annual and diurnal fluctuations are small, and in some places, especially those which lie somewhat out of the force of the south-west monsoon, the climate is perhaps the most equable in the world.

At some stations on the southern coast the temperature of the sun's zenith is lower than at the declination, in consequence of the occurrence of clouds and rain, brought up by the south-west monsoon.

In the interior, on the plateaux of low elevation, the temperature is greater, and the yearly and diurnal fluctuations are more marked. On the hill stations (6000 to 8000 feet above sea-level), the mean temperature is much less; the fluctuations are sometimes great, sometimes inconsiderable.

The influence of winds is very great on the temperature; the sea-winds lowering it, hot land-winds raising it greatly.

The temperature in the sun's rays ranges as high as 166° or 170°, but the mean sun-rays' temperature is, with great differences in different places, between 130° and 160° at the hottest time of the year.

The air temperature of a few of the principal stations is subjoined, merely to give an idea of the amount of heat in different parts of the country.[1] Those of the hill stations are given under the proper headings.

The increase and the amplitude of the yearly fluctuation is thus seen as we pass to the north, and ascend above sea-level.

In several places there are great undulations of temperature from hot land-winds, or from sea or shore breezes, or from mountain currents, which give to the place local peculiarities of temperature.

To get the same mean annual temperature as in England, it would be necessary that 9500 feet be ascended in places south of lat. 20°; between

[1] These are taken from Mr Glaisher's very excellent report in the *Indian Sanitary Commission*, which must be consulted for fuller details. Very full meteorological returns are now being given in the Reports of the Sanitary Commissioners for the three presidencies, and these will ultimately supersede Mr Glaisher's tables.

lat. 20° and 26°, 9000 feet; between lat. 26° and 30°, 8700 feet; and north of lat. 30°, 8500.

The mean monthly temperatures would, however, at such elevations, differ somewhat from those of England. Speaking generally, an elevation of 5000 to 6000 feet will give over the whole of India a mean annual temperature about 10° higher than that of England, and with a rather smaller range.

Mr Glaisher has calculated that in the cold months the decrease of temperature is 1°·05 for each 300 feet of ascent, but increases from March to August to 4°·5, and then gradually declines. These results are not accordant with the results of balloon ascents in this climate.

Mean Temperature, and Height above Sea-Level, of some of the larger Stations.

Months.	Calcutta, Fort William, 8 feet above sea-level.	Panjāb, generally 800 to 900 ft. above sea-level.	Peshawar, 1056 feet above sea-level.	Madras, Fort St George, at sea-level.	Bangalore, 3000 ft. above sea-level, 1 year only.	Bombay, at sea-level.	Poonah, 1809 feet above sea-level.	Belgaum, 2260 feet above sea-level.
Mean of year,	82°	73°	74°	82°	76°	80°	78°	74°
January,	70	54	52	76	69	74	72	72
February,	75	60	55	78	73	76	75	75
March,	83	68	65	80	79	80	79	78
April,	88	77	75	84	79	83	83	81
May,	89	86	88	87	82	86	85	78
June,	87	89	91	88	77	83	81	75
July,	85	87	91	85	77	81	77	73
August,	85	86	88	85	75	81	76	72
September,	85	83	84	84	76	80	77	74
October,	84	76	73	82	75	82	79	74
November,	78	61	64	79	73	79	76	72
December,	72	55	56	76	71	76	73	70
Amplitude of yearly fluctuation (difference between hottest and coldest months),	19	35	39	12	13	12	13	11

Humidity.—The humidity of different parts of India varies extremely; there are climates of extreme humidity—either flat hot plains, like Lower Scinde, where, without rain, the hot air is frequently almost saturated, and may contain 10 or 11 grains of vapour in a cubic foot; or mountain ranges like Dodabetta, in Madras, 8640 feet above sea-level, where, during the rainy season, the air is also almost saturated; a copious rain, at certain times of the year, may make the air excessively moist, as on the Malabar coast, the coast of Tenasserim, or on the Khasyah Hills, where the south-west monsoon parts with its vapours in enormous quantities.

On the other hand, on the elevated tableland of the interior, and on the hot plains of North-West India, during the dry season, or in the places exposed to the land-winds at any part, the air is excessively dry. In the Deccan the annual average of the relative humidity is only 55 per cent. of saturation (Sykes). Mr Glaisher has given the humidity of many places. A few stations are here given:—

Mean Humidity per cent.

	Fort William.	Madras, Fort St George.	Bombay.	Benares.	Meerut.	Peshawar.	Bellary.	Secunderabad.	Poonah.	Kurrachi.	Belgaum.
Mean maximum, .	81	79	85	94	84	73	76	84	79	80	84
,, minimum, .	59	61	67	44	54	41	40	40	42	48	43
Yearly mean, . .	68	72	73	69	67	55	56	54	53	62	64

The mean relative humidity at Greenwich is 82, varying from 89 in December and January to 76 in July. Calcutta, therefore, with a mean yearly humidity of 68 per cent. of saturation, is, as far as relative humidity (*i.e.*, evaporating power) goes, less moist than England, and the evaporating power is also increased by the higher temperature.

Rain.—The amount of rain and the period of fall vary exceedingly in the different places. It is chiefly regulated by the monsoons.

When the south-west monsoon, loaded with vapour, first strikes on high land, as on the Western Ghauts, on the Malabar coast, or on the mountains of Tenasserim, and especially on the mountains of the Khasyah Hills, at some points of which it meets with a still colder air, a deluge of rain falls; as, for example, at Cannanore (Malabar), 121 inches; Mahableshwar, 253 inches; Moulmein (Tenasserim), 180 inches; Cherrapunji (Khasyah Hills), 600 inches. On the other hand, even in places near the sea, if there is no high land, and the temperature is high, scarcely any rain falls; as in Aden, on the south coast of Arabia, or at Kota, in Scinde, where the amount is only 1·8 annually, or Kurrachi, where the yearly average is only 4·6 inches. Or in inland districts, the south-west monsoon, having lost most of its water as it passed over the hills, may be comparatively dry, as at Nusserabad, where only 15·8 inches fall per annum, or Peshāwar, where there are 13·7 inches annually.

The yearly amount of rain in some of the principal stations is—

	Average.
Calcutta, . . .	56·8
Madras, . . .	50
Bombay, . . .	72·7
Bengal Presidency—	
Dinapore, . . .	31·1
Berhampore, . .	49·8
Benares, . . .	37·4
Ghazipur, . . .	41·4
Azimghar, . . .	40
Agra, . . .	27·9
Delhi, . . .	25·1
Meerut, . . .	18
Panjāb, . . .	56·6

	Average.
Madras Presidency—	
Bellary, . . .	21·7
Bangalore, . .	35
Trichinopoly, . .	30·6
Secunderabad, . .	34·6
Bombay Presidency—	
Belgaum, . . .	51·5
Poonah, . . .	27·6
Neemuch, . . .	34·1
Kampti, . . .	21·8

Winds.—The general winds of India are the north-east monsoon, which is, in fact, the great north-east trade-wind, and the south-west monsoon, a wind caused by the aspiration of the hot earth of the continent of Asia when the sun is at its northern declination. During part of the year (May to August) the south-west monsoon forces back the trade-wind or throws it

up, for at great altitudes the north-east monsoon blows through the whole year, and the south-west monsoon is below it. But, in addition, there are an immense number of local winds, which are caused by the effect of hills on the monsoons, or are cold currents from hills, or sea breezes, or shore-winds caused by the contact of sea breezes and other winds, or by the first feeble action of the south-west monsoon before it has completely driven back the north-east trade. The south-west monsoon is in most of its course loaded with vapour; the north-east is, on the contrary, a colder and drier wind, except when at certain times of the year, in passing over the Indian Ocean, it takes up some water, and reaches the Coromandel coast and Ceylon as a moist and rain-carrying wind.

The hot land-winds are caused by both the south-west monsoon, after it has parted with its moisture and got warmed by the hot central plains, and the north-east monsoon; the temperature is very great, and the relative humidity very small, the difference between the dry and the wet bulb being sometimes 15° to 25° Fahr.

Pressure of the Air.—On this point little need be said. The barometer is very steady at most sea-coast stations, with regular diurnal oscillations, chiefly caused by alteration in humidity. An elevation of 5000 feet lowers the barometer to nearly 26 inches.

Electricity.—On this point few, if any, experiments have been made; the air is extremely charged with electricity, especially in the dry season, and the dust-storms are attended with marked disturbance of the electrometer.[1]

Effects of Climate.—The estimation of the effects of such various climates is a task of great difficulty. Long continued high temperature, alternations of great atmospheric dryness and moisture, rapidly moving and perhaps dry and hot air, are common conditions at many stations; at others, great heat during part of the year is followed by weather so cold that even in England it would be thought keen. When to these influences the development of malaria is added, enough has been said to show that, *a priori*, we can feel certain that the natives of temperate climates will not support such a climate without influence on health, and the selection of healthy spots for troops is a matter of the greatest moment as affects both health and comfort. This much being said, it must at the same time be asserted that, malaria excepted, the influences of climate are not the chief causes of sickness.

The location of troops should be governed by two or three conditions—1, military necessities; 2, convenience; 3, conditions of health. The second of these conditions is, however, a mere question of administration; every place can be made convenient in these days of railway and easy locomotion. Military necessity and health are the only real considerations which should guide our choice. The vital military points must be held with the necessary forces, and then the whole of the remaining troops can be located on the most healthy spots.

These spots cannot be in the plains. Let any one look at a geological map of India, and see the vast tract of alluvial soil which stretches from the loose soil of Calcutta, formed by the deposit of a tidal estuary, up past Cawnpore, Delhi, to the vast plains of the Panjāb, Scinde, and Belūchistan. The whole of that space is more or less malarious, and will continue to be so until, in the course of centuries, it is brought into complete tillage, drained, and cultivated. Moreover, heat alone without malaria tells upon

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[1] See Baddeley's *Whirlwinds and Dust Storms of India* (1860), for a very good account of these singular storms.

the European frame, lessens the amount of respiration and circulation, and lowers digestive power.

In looking for healthy spots, where temperature is less tropical, and malarious exhalations less abundant, there are only two classes of localities which can be chosen—seaside places and highlands.

Seaside Places.—The advantages of a locality of this kind are, the reduction in temperature caused by the expanse of water, the absence of excessive dryness of the air, and the frequent occurrence of breezes from the sea. All these advantages may be counteracted by the other features of the place; by a damp alluvial soil, bad water, &c.

It does not appear that many eligible places have yet been found, and as a substitute in Bengal, the Europeans from Calcutta sometimes live on board a steamer anchored off the sandheads, thus literally carrying out a suggestion of Lind in the West Indies a century ago.

In the Bay of Bengal, Waltair, in the northern division of Madras, is one of the best.[1] Cape Calimere (28 miles south of Nagapatam) also appears to have many advantages (Macpherson). On the opposite coast, Cape Negrais, on the Burmese coast, was pointed out as long ago as 1825, by Sir Ranald Martin, as a good marine sanitarium, and Amherst, in Tenasserim, and some of the islands down the coast towards Mergui, are beautiful spots for such a purpose, being, however, unfortunately at a great distance from the large military stations, and not well supplied with food.

On the Bombay side, at Sedashagar or Beitkal Bay, between Mangalore and Goa, a spur of the Western Ghauts projects into the sea for upwards of a mile, and forms an admirable sea-coast sanitarium (Macpherson).

All these sea-coast stations seem adapted for organic visceral affections and dysentery, but they are not so well calculated for permanent stations for healthy men. Probably they are rather sanitaria than stations.

Highlands.—The location of troops on the hills or on elevated tablelands has long been considered by the best army medical officers as the most important sanitary measure which can be adopted. Not only does such a location improve greatly the vigour of the men, who on the hill stations preserve the healthy, ruddy hue of the European, but it prevents many diseases. If properly selected, the vast class of malarious diseases disappears; liver diseases are less common, and bowel complaints, in some stations at any rate, are neither so frequent nor so violent. Digestion and blood nutrition are greatly improved. Moreover, a proper degree of exercise can be taken, and the best personal hygienic rules easily observed.

Indian surgeons appear, however, to think the hill stations not adapted for cardiac and respiratory complaints; it is possible that this objection is theoretical. The latest European experience is to the effect that phthisis is singularly benefited by even moderate, still more perhaps by great elevation; that anæmia and faulty blood nutrition are cured by high positions with great rapidity, and that if the elevation be not too great (perhaps not over 3000 feet) even chronic heart diseases are improved. In some of the hill stations of India bowel complaints were formerly so frequent as to give rise to the term "hill diarrhœa." The elevation was credited with an effect which it never produced, for, not to speak of other parts of the world, there are stations in India itself (Darjīling, for example), as high as any other, where the so-called hill diarrhœa was unknown. At Newera Ellia, in Ceylon, too, if the simple condition of mountain elevation could have produced diarrhœa, it would have been present. The cause of the hill diarrhœa

[1] Evidence of Dr Maclean in *India Report*, p. 139.

was certainly, in many stations, unwholesome drinking water; whether or not this was the case in all is uncertain. Some of the hill stations are said not to be adapted for rheumatic cases; in other instances (as at Sabāthū) rheumatism is much benefited. From reading the reports from these stations, it is more probable that damp barracks, and not the station, have been in some cases the cause of the rheumatism.

But it must be noticed that the evidence given before the Indian Sanitary Commission shows, on all or almost all hill stations, a most lamentable want of the commonest sanitary appliances. At great expense men are sent up to the hills, where everything is, or was, left undone which could make that expense profitable. It appeared to be thought sufficient to ascend 6000 feet to abandon all the most obvious sanitary rules, without which no place can be healthy.

Admitting, as a point now amply proved, that stations of elevation are the proper localities for all troops not detained in the plains by imperative military reasons, the following questions are still not completely answered:—

1. What amount of elevation is the best? We have seen that to reduce the temperature to the English mean, 5000 to 6000 feet must on an average be ascended. But then such an elevation brings with it certain inconveniences, viz., in some stations much rain and even fog at certain times of the year, and cold winds. However unpleasant this may be, it yet seems clear, from the experience of Newera Ellia, in Ceylon, that damp and cold are not hurtful. But it must also be said that, with a proper selection, dry localities can be found at this elevation.

From 3000 to 4000 feet have been recommended, especially to avoid the conditions just mentioned. Whether places of this height are equal in salubrity to the colder and higher points is uncertain.

Even at 6000 feet there may be marsh land, though it is not very malarious. Malarious fever has been known during the rains at Kasauli (6400 feet) and Sabāthū (4000), and other Himalayan stations. Malaria may, however, drift up valleys to a great height,[1] but, apart from this, it seems likely that 5000 feet, and probably 4000, will perfectly secure from malaria. Probably, indeed, a less height will be found effectual.

At no point do hot land-winds occur, or at any rate endure, at above 4000 feet. On the whole, it would appear probable that the best localities are above 5000 feet, but below 7000.

2. What stations are the best—the tops of solitary hills, spurs of high mountains, or elevated tablelands?

Ranald Martin has called especial attention to the solitary hills, rising as they do sometimes from an almost level plain to 2000 and 3000 feet. Such mountain islands seem especially adapted for troops if there is sufficient space at the top. They are free from ravines conducting cold air from higher land, and are often less rainy than the spurs of loftier hills.

The spurs of the Himalayas, however, present many eligible spots, and so do some tablelands. And perhaps, on the whole, if the elevation is sufficient, it is not a matter of much importance which of these formations is chosen; other circumstances, viz., purity of water, space, ease of access, and supplies, &c., will generally decide.

In choosing hill stations, the points discussed in the chapter on SOILS should be carefully considered, and it is always desirable to have a trial for a year or two before the station is permanently fixed.

In all the presidencies of India elevated spots where troops can be

[1] It has drifted up even to the summits of the Neilgherries, 7000 or 8000 feet.—*Indian Sanitary Report*, Mr Elliot's Evidence, vol. i. p. 250.

cantoned exist in abundance.[1] The following table (p. 628), copied from Dr Macpherson's work, gives some of the principal hill stations. Fresh stations are, however, being constantly discovered, and it seems now certain that there is scarcely any important strategical point without an elevated site near it.

Near Naini Tal, in Kumaon, are Almorah (5500 feet) and Hawalbagh (4000 feet), both well spoken of. Kanawar (5000 or 6000 feet), in the valley of the Sutlej, has a delicious climate; and Chini (about 100 miles from Simla) is a most desirable spot.

Passing down from the north-west towards Calcutta, Dr M'Clellan found elevated land within 100 miles of Allahabad; and in the south there are the Travancore Mountains, with numerous good sites.

If, then, the mass of the troops are cantoned on elevated places, the disadvantages of climate are almost removed. The Indian Sanitary Commissioners recommended that one-third of the force shall be in the hills, and that enfeebled men and recruits especially shall be sent there. But it is to be hoped that not only one-third, but a large majority of the troops will eventually be placed there.

Sub-Section II.—Diseases of the Natives.

It is impossible that Europeans can be perfectly isolated from the nations among whom they serve; they have suffered from the pestilential diseases of the Hindus, but still it is wonderful that they have not suffered more. Cholera is the chief disease, which, arising in the native population, scourges their conquerors. Some fevers also—relapsing fever, perhaps a "febris icterodes," or bilious remittent, which has attacked Europeans—have had their origin, or at any rate their conditions of spread, in the dense populations of native cities. Happily the Black Death (the Maha Mari, or Pali plague) has never yet spread to the troops, and has indeed been confined within narrow limits. Still these pestilences among the native population are an ever-present menace to Europeans, and, as in the case of cholera, may pass to them at any time. Cholera, certainly, will never be extirpated until attacked in its strongholds, among the miserable dwellings which make so large a part of every Oriental city. In 1867 there were some cases among the troops of the contagious fever which has caused so much mortality in many of the Bengal jails. The exact influence on Europeans of the customs and modes of life of the natives of India has not been made an object of special study, but it cannot be inconsiderable. In many places the Europeans and the natives are in close neighbourhood, and the air at all times, and often the water, must be influenced by the social life of the native races. The proximity to large cities or bazaars is indeed often alluded to by army officers as influencing the health of their men; it would be very interesting to know the precise effect. The sanitary condition of almost all the large native towns, and the sanitary habits of the country people, are as bad as can be. Bad water, fœtid air, want of sewage removal, and personal habits

[1] See the evidence in the *Indian Sanitary Report* (vol. i.) of Sir R. Martin, Mr Elliott Dr Maclean, Dr Alexander Grant, Mr Montgomery Martin, and others. Also most instructive reports by Mr Macpherson, *Indian Report*, vol. ii. p. 622; and by Dr Alexander Grant, *Indian Annals*. On the location of troops reference may also be made to the late Surgeon-General Dr Beatson's very decided opinion on the necessity of placing on the hills all the men who can be spared from the military posts in the plains. No more valuable opinion could be given on such a point than that of an officer who had the largest possible experience, and the best opportunities of forming a correct judgment. (See his *Report in the Army Med. Report*, vol. viii. p. 347.) Sir William Muir also urged this point, and the result is that gradually more and more troops are being located on the hills.

Names of Hill Stations.			Mean Temperature outside in the Shade.												Ascertained greatest Elevation.	Average Fall of Rain in Inches.
			January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
Bengal Presidency.	Darjīling,		40	41	51	55	61	62	63	64	63	55	50	44	8000	132
	Simla,		40	44	53	61	66	80	75	78	70	67	52	46	8000	70
	Landaur,		35	40	51	...	...	...	...	68	64	49	46	46	7300	...
	Marrī,		...	...	...	...	...	69	68	66	62	62	...	...	6786	...
	Kasauli,		42	47	58	64	77	73	70	70	72	66	...	...	6400	70
	Naini Tal,		42	46	56	61	69	69	67	69	65	61	50	47	6200	83
	Dagshai,		42	47	57	64	69	71	72	68	66	62	54	53	6000	70
	Sabāthū,		...	...	...	77	81	84	79	77	...	...	...	...	4000	70
Madras Presidency.	Ūtacamand,	Neil gherry range,	54	56	60	61	61	57	63	63	62	56	54	53	7361	60
	Kotagherry,		59	60	61	63	63	64	65	65	64	62	60	59	6100	55
	Wellington,		59	61	67	68	68	64	70	70	70	63	61	60	5840	50
	Kūnūr,		60	62	68	68	68	65	70	70	70	65	62	62	5161	50
	Palneys,		51	53	60	61	...	...	..	...	...	...	...	...	7000	...
	Mercara,		53	56	61	64	44	66	65	65	64	65	63	56	4500	100
	Annamallays,		...	...	...	...	...	...	...	...	66	56	...	...	6800	...
	Shevaroys,		65	65	68	71	71	68	68	68	67	66	66	65	5260	40
	Ramandroog,		70	76	80	80	75	73	71	70	70	71	71	67	3400	46
	Checuldah,		60	60	70	83	83	71	...	...	...	...	71	71	3600	...
	Sindwarrah,		An average of 8° lower than the station of Kamptee.													
	Mathur,		Do. 11° do. do.													
Bombay Presidency.	Mahableshwar,		63	65	72	74	72	67	63	64	64	66	64	63	4700	240
	Purandhar,		67	73	77	78	73	70	67	65	67	71	69	64	4200	73
	Mount Abū,		61	61	79	77	77	77	69	69	69	69	69	71	4015	79

of uncleanliness abound everywhere. The Report of the India Sanitary Commission, and the activity of the Indian officials in the Sanitary Departments, are now beginning a series of changes in this respect, which will probably change, *in toto*, the medical history of India.

SUB-SECTION III.—SPECIAL HYGIENIC CONDITIONS.

The special hygienic conditions (apart from locality) under which the soldier serves in India have been the main causes of excess of disease. This subject has received a searching inquiry from the Sanitary Commissioners.[1] They declare, and after reading the station reports and the evidence given before them no one will doubt the assertion, that while malaria, extremes of temperature, moisture, and variability of temperature cause a certain amount of sickness, "there are other causes of a very active kind, connected with stations, barracks, hospitals, and the habits of the men, of the same nature as those which are known in colder climates, to occasion attacks of those very diseases from which the Indian army suffer so severely."

And the Commissioners enumerate a list of causes connected with unhealthy stations, bad barracks, overcrowding, impure air and water, bad drainage, imperfect ablution, inferior rations and cooking, &c.

In fact, no doubt can exist in the minds of all who have studied the subject that these form the most potent class of causes which affect health.

SUB-SECTION IV.—HABITS AND CUSTOMS OF THE TROOPS.

The habits of the men and the customs of service were, however, also great causes of diseases, and are still so to some extent.

The men were, as a rule, intemperate, great smokers, and indisposed for exertion. It has, indeed, been pointed out with truth, that in proportion to their amount of exercise the men were much overfed, and some diseases of the liver appear to result directly from this simple condition.

The want of exercise is not always the fault of the men. The early morning hours, and often the evening, are occupied with parades; in the period between, the men used to be confined to barracks, and are still sometimes so. Here, listless, unoccupied, and devoured with ennui, they passed the weary day, lying down perhaps for hours daily, or lounging on chairs smoking.

This forced confinement to barracks is indeed an evil often greater than that it is intended to remove. To prevent men from passing out into the sun they are compelled to remain in a hot, often ill-ventilated room, worse for health than the intensest rays of the sun,[2] that scape-goat of almost every fault and vice of Indian life.

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[1] *Report of the Commissioners on the Sanitary State of the Army in India*, 1863. *Report*, p. 79, published in 1864 in small bulk.

[2] The late Dr Parkes wrote—"I shall never forget the sufferings of the men in the old barracks at Madras. We arrived there from Moulmein, where the men had never been confined to barracks, and where, during two hot seasons, no injury had resulted from allowing them to go out when they liked. On arrival at Madras, in accordance with invariable custom, the men were confined to barracks. They lay all day on their beds, reeking with perspiration; the place was so small and ventilation so bad, that the heat was perfectly intolerable in the barracks, though the sun's rays were quite bearable. The sufferings were extreme. When the afternoon came, more injury had been done by the hot and impure air than exposure to the sun's rays could have caused.

"At Moulmein, in Tenasserim, at one time, two European regiments served together. The barracks of each were perfectly healthy; the food and duties were the same; yet one showed a sick list and mortality always much greater than the other. Serving in the station shortly afterwards, I was so struck by this difference that I went over all the returns and reports in

All these causes have been summed up by Miss Nightingale in some of those telling sentences which have done more than anything else to force attention to these vital questions.[1]

Of late years a great change has taken place in the habits of the men,—more open air exercises of all kinds; and in the cooler stations athletic sports and cricket have been encouraged; in some of the hill stations the troops have been employed in making roads and public works, and the practice of trades has been promoted. Were the troops chiefly on the hills, as much exercise as at home would be possible, and the men would preserve their European vigour and appearance. But even in the plains exercise is necessary, and if it be taken at proper times (*i.e.*, with avoidance of the three or four hottest hours), and with proper precautions, such as keeping the head and spine well covered and cool, putting on after profuse sweating dry and thin mixed cotton and woollen underclothes, and protecting the loins and abdomen with a silk or flannel sash, and avoiding stimulants before and during the exercise, all men would be benefited even by very great exercise.

The pale, feeble appearance of persons who keep much in the darkened houses is really owing more to the absence of light and to the unhealthy and sedentary life than to the effect of the climate.

The subject of clothing has been already referred to. In Algeria, as in India, much good has been ascribed to the use of very large flannel belts, which the French suspend from the shoulders, a plan better adapted for comfort than the so-called cholera belts of India.

With regard especially to diet, two points must be considered :—

1. What amount of food should be taken? In India, as in all parts of the world, food should be taken in proportion to the mechanical work done by the body, and to the equivalent of mechanical energy, viz., animal heat.

High temperature, as lessening the loss of the body heat, must *pro tanto* lessen the need of food to supply the temperature; and it has been supposed that the diet of men in cold countries (Arctic regions) and in hot contrasted remarkably in respect of the amount of carboniferous food taken by each. But although it is certain that large quantities of meat and fat are taken by men living in or arriving in cold countries, it is now known that the natives of some of the hottest parts of the world take immense quantities of both fats and starches. In fact, both these substances are taken to supply mechanical energy directly, as well as animal heat. It is not, in fact, yet known what amount of lessening of food, or what kind of lessening, the increased heat of the tropics demands, or whether any is demanded, for exact experiments are wanting. Our best guide at present for the quantity of food to be taken in the tropics is to apportion it to the amount of mechanical work done, as in temperate climates. In India, as elsewhere, it must be in

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the staff-surgeon's office to make out the cause; the only difference I could detect was, that in the sickly regiment the men were confined to barracks, in the other they were allowed to go about as they pleased. Many years afterwards I met with a medical officer who had served in the sickly regiment, and learned from him that he had always considered the confinement to barracks, and the want of exercise, and the impure air breathed by that system almost night and day, to have been the cause of a disparity so striking. No one would recommend imprudent exposure to the sun; men may be trusted to avoid its intensest rays; but to reduce men to enforced idleness for many hours, and to confine them in the small space of a barrack-room, is not the way of meeting the evil. (On this point see also Dr Clark's observations on want of exercise as compared with exposure to the sun on the West Coast of Africa.) On this point, as in many others, the statements of Dr Kenneth Mackinnon are deserving of great attention. His remarks on the desirability of exercise, even in the trying climate of Tirhoot in Bengal, are very striking. (*A Treatise on Public Health*, by Kenneth Mackinnon, M.D., Cawnpore, 1848, pp. 27 and 145.) He strongly recommended open sheds and gymnasia, and these are now being adopted."

[1] *How People may Live and not Die in India*, by Florence Nightingale, 1863.

balance with exercise. The points then to be considered are the amounts of daily food and of daily exercise, and, by means of the tables formerly given, and by knowing the habits of the men, little difficulty will be found in determining the proper ration quantity of food with accuracy.

In considering the amount of food, it must be remembered that the soldier almost always buys additional food, and often eats much more than his ration. Some years ago Dr Macnamara found the troops in Bengal taking no less than 76 ounces of food (*i.e.*, water-containing food), while the regulation ration was only 52 ounces, so that these men were largely over-feeding. And Dr Dempster[1] states that the majority of the recruits from Scotland and England eat in the hot weather in India much more animal food than in the coldest seasons in their native countries.[2]

It would therefore seem that illness may arise in India from excess of food, but it is not the regulation ration which produces it, but the additional purchased food, which is often of bad quality, or the extreme idleness of the men, in which case even the regulation ration is too much. The only remedy is instruction of the men in what is good for them, and no men are so stupid as not to perceive what is best for their own comfort and happiness when it is once pointed out to them.

In addition, the soldier in India had till very lately the spirit ration (now lessened to one-half), which has the effect of lessening the power of appropriation of food, though not always the appetite, and thus indirectly may cause over-feeding.

2. Admitting (till better observations are made) that men in the tropics, undergoing as much exertion as at home, will demand as much food, and in the same proportions, as far as the four classes of aliment are concerned (and all physiological evidence goes to show that this must be the case, and that not external temperature, *per se*, but the work of the body, is the chief measure of food), the next question is whether the different articles of the diet should be altered; whether, for example, the same amount of nitrogen being given, it should be contained in vegetable or animal food?

It has been stated by several of the best observers in the tropics that those who eat largely of animal food are less healthy than those who take more vegetable food; and Friedel, in his work on China, has again directed attention to the fact[3] that the amount of digestive and hepatic disease is much greater among the English than among any other European settlers in China. But whether this is owing to excessive animal food, or excess generally in all food, and to too much wine, beer, and spirits, is not certain. The diet is probably too rich as a whole.

Supposing meat is taken in proper but not excessive quantity with farinaceous food, as at home, is it less healthy than a quantity of vegetable food containing an equivalent amount of nitrogen? On this point strict scientific evidence has not been produced. With regard to excess of animal food there is no doubt; but animal food in moderation has not been shown to be more active in causing liver complaints in India than at home.

Considering, indeed, how important it is, when the digestive organs have been accustomed to one sort of diet, not to change it suddenly and completely, it seems very doubtful whether it would be desirable for the European arriving in India at once to give up all previous habits, and to commence an entirely different kind of diet.

[1] *Indian Sanitary Report—Evidence.*

[2] Colonel Sykes long ago directed particular attention to this point, stating with perfect truth that the soldier in India is over-stimulated by food and drink and under-stimulated by bodily and mental exercise.

[3] Already noticed as regards India and the Mauritius

It is possible, however, that the meat standard of England might be somewhat reduced, and the bread, flour, and leguminosæ increased. This is not the opinion, however, of some of those who have lately paid particular attention to Indian rations (Dr C. A. Gordon and Dr Inglis),[1] and who believe that the amount of meat is even too small.

It has often been said that Europeans in India should imitate the natives in their food, but this opinion is based on a misconception. The use of ages has accustomed the Hindu to taking large quantities of rice, with pulses or corn ; put an European on this diet, and he could not at first digest it ; the very bulk would be too much for him. The Hindu, with this diet, is obliged to take large quantities of condiments (pepper, &c.). The European who did the same would produce acute gastric catarrh and hepatic congestion in a very short time ; in fact, as already stated, one great fault of the diet of Europeans arriving in India is too great use of this part of the native diet.

Two points about the diet of India seem quite clear. One is, that spirits are most hurtful, and that even wine and beer must be taken in great moderation. Of the two beverages, light wines (clarets), which are now happily coming into use in India for the officers, are the best. For the men good beer should be provided, but it is important to teach the men moderation. The allowance per man per diem should never be more than a quart, and men would find themselves healthier with a single pint per day. But it would seem probable that, especially in the hot stations and seasons, entire abstinence should be the rule, and that infusions of tea and coffee are the best beverages.[2]

The other point is, that in the tropics there is perhaps even a greater tendency to scurvy than at home ; the use of fruits, then, is of great importance, and, whenever practicable, the growth of fruit trees should be encouraged in the neighbourhood of stations. In some stations (Mūltān) lime juice has been issued with the greatest benefit when vegetables were scarce.

Health of the Troops.

India presents in many respects the same history as our other tropical possessions. In former years there was a large mortality among Europeans, attributed usually to the climate, instead of being put down to its proper causes, viz., a reckless mode of living amidst the most insanitary conditions. As years have passed, the same gradual improvement has occurred in India as in the West Indies. Habits have improved, and the conditions of life have been slowly altered for the better. This change has been going on for years, and there has been an astonishing progress since the Mutiny. Much, no doubt, remains to be done, but the fall in mortality and in sickness has been so marked in all the Presidencies as to lead us to hope that in a few more years the Indian service will, like the West Indian, be almost as healthy as the home service. It cannot be rash to anticipate such a result, since so great an improvement has already taken place, for the mortality even now has fallen two-thirds, compared with that of thirty years ago.

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[1] *Op. cit.*, and *Army Medical Reports*, vol. v. p. 380.

[2] The drinks which the private soldier often buys in the bazaars in India are of the worst description ; arrack mixed with cayenne and other pungent substances, or fermented toddy mixed with peppers and narcotics, or drugged beer, are common drinks. It would be easy to put a stop to this by legislative enactment.

The following table shows this :—

Earlier Years.—Mortality of Europeans per 1000 *of Strength.*

Years and Authorities.[1]	Bengal Presidency.	Bombay Presidency.	Madras Presidency.
1845–54 (Chevers), . . .	63·38	60·20	59·20
1838–56 (Queen's troops alone—Balfour), ...	79·20	61·10	62·90
1806–56 (Company's troops alone—Indian Sanitary Commissioners, ...	74·10	66·00	63·50

In 1812–16, in the Bengal Presidency, the deaths averaged 96·5 per 1000; in the Bombay Presidency, in 1819–20, the deaths were 80 per 1000.

The above mean mortality includes every loss; in some years it was, of course, greater, in some less; but on the whole, large every year, with a few exceptions, till the year 1856. After the Mutiny, about the year 1860, the sanitary improvements and the greater care of the troops which had been gradually taking place received an immense impulse. The results are shown below.

Later Years.—Mortality of Europeans per 1000 *of Strength.*

Years and Authorities.	Bengal Presidency.	Madras Presidency.	Bombay Presidency.
	Total Mortality.	Total Mortality.	Total Mortality.
1860–9 (10 years—Balfour), . .	31·27	22·53	22·58
1870–79 (10 years—*A. M. D. Reports*),[2]	20·17	18·97	16·37
1879–83 (5 years),[2] . . .	20·71	12·43	15·49

Causes of Sickness and Death.

The causes of diseases and deaths of Europeans are given in the follow-

[1] The chief statistics of the forces in India are contained in—

1. Numerous scattered papers in the various Indian medical periodicals for the last sixty years, referring chiefly to the health of one Presidency or of regiments or forces occupying small districts.

2. Summaries of the whole, by Colonel Sykes (for twenty years ending 1847, *Statistical Journal*, vol. x.); Sir Ranald Martin (*Influence of Tropical Climates*, 2nd edition); Mr Ewart (*Vital Statistics of European and Native Armies*, 1859); Drs Waring and Norman Chevers (*Indian Annals*, 1858–1862); and, as far as officers and civilians are concerned, by Colonel Henderson (*Asiatic Researches*, vol. xx.) and Mr Hugh Macpherson.

3. Official documents, the most important of which are contained in the *Indian Sanitary Report*; in the yearly *Army Medical Department Reports* since 1860; in the various *Reports of the Sanitary Commissioners* in the three Presidencies, in the invaluable Returns of the late Dr Bryden, and in the municipal and other official reports sent in from towns or districts. At present the most valuable information is being collected and published in India of the health, not only of the European and native armies, but of the civil population; and records of population and of births and deaths are now systematically made. For the first time the Indian Government is gradually obtaining a view of the state of health of the numerous nations it controls.

The Reports from Bengal (*Annual Reports of the Sanitary Commissioner with the Government of India*) and those from Madras and Bombay are models of their kind, and must have a great effect on the health of the inhabitants of all India. The information given in these excellent Reports is so copious, that it is impossible to give any adequate account of it in this short chapter. Only the most striking points are noticed.

[2] Including deaths of Invalids.

ing table.[1] During the period of five years there was some cholera in Bengal in the years 1879, 1880, and 1881:—

Admissions and Deaths per 1000 *of Strength.*

Causes.	Bengal.				Madras.				Bombay.			
	1879–83.		1884.		1879–83.		1884.		1879–83.		1884.	
	Adm.	Died.	Adm.	Died.	Adm.	Died.	Adm.	Died.	Adm.	Died.	Adm.	Died.
Cholera,	4·5	3·46	2·1	1·33	2·0	1·14	1·1	1·02	0·7	0·44	6·2	4·85
Paroxysmal fevers,	582·0	1·34	564·3	0·36	204·3	0·34	80·1	...	702·2	1·72	365·2	1·30
Enteric fever,	7·8	3·00	12·5	3·29	3·6	1·48	11·9	1·66	4·3	2·04	9·0	2·05
Other continued fevers,	139·4	0·16	109·5	0·06	77·7	0·21	84·2	...	113·6	0·16	112·6	0·84
Small-pox,	1·0	0·08	1·5	0·18	0·5	0·04	1·8	0·09	0·3	0·04	0·8	0·09
Other eruptive fevers, (including Dengue),	2·1	0·01	0·8	...	0·5	...	1·2	...	0·8	...	0·7	..
Rheumatism,	38·1	0·02	34·8	0·06	29·6	0·02	31·4	...	34·8	0·14	27·1	...
Syphilis, primary,	88·1	..	86·7	...	105·9	...	101·4	...	83·9	0·02	90·1	...
,, secondary,	23·9	0·03	24·4	...	23·1	0·06	25·2	...	22·5	...	19·0	...
Gonorrhœa,	129·1	0·01	149·5	...	114·6	...	133·6	...	113·6	...	148·4	...
Phthisis, Scrofula, &c.,	7·0	1·45	7·2	1·09	6·5	0·97	5·4	0·55	7·2	1·21	8·1	1·03
Respiratory :—												
Pneumonia,	55·4	1·50	4·0	0·47	32·1	0·47	1·1	0·09	51·8	1·56	6·3	1·30
Bronchitis, &c.,			41·8	0·33			25·3				34·1	0·36
Circulatory :—												
Heart, &c.,	16·2	0·63	14·5	0·24	18·5	0·78	14·6	0·19	16·8	0·67	0·2	...
Aneurysm,			0·2	0·03							16·7	0·37
Nervous,	20·3	2·43	19·5	1·33	15·4	1·41	14·8	0·93	15·3	1·80	17·8	1·68
Eye,	15·6	...	16·8	...	15·3	...	12·6	...	14·9	...	14·5	...
Digestive :—Liver,	236·9	4·08	31·2	1·00	239·9	3·33	44·1	2·18	210·7	3·41	26·6	1·12
,, Dysentery,			21·6	0·18			56·0	0·46			25·3	0·94
,, Diarrhœa,			50·8	0·03			42·0	0·09			46·2	0·19
,, Other,			121·8	0·27			87·1	...			115·5	0·74
Urinary (excluding gonorrhœa),	10·6	0·23	11·9	...	8·0	0·25	14·0	0·19	9·7	0·24	11·8	0·19
Injuries and poisons,	104·9	1·80	132·4	1·40	105·2	1·73	116·1	1·29	109·6	1·64	122·7	2·24
All other causes,	188·8	0·48	184·8	0·45	192·8	0·20	101·2	0·51	188·1	0·50	190·4	0·47
Total,	1671·7	20·71	1644·6	12·10	1195·5	12·43	1106·2	9·25	1699·9	15·59	1415·3	19·76

The following table shows the distribution of mortality according to age:—

Deaths per 1000 *of Strength at the Ages named.*

All India.	Under 20 years.	20 and under 25.	25 and under 30.	30 and under 35.	35 and under 40.	40 and upwards.
1860–9 (10 years—Balfour),	9·25	17·59	24·63	34·17	44·13	60·88
1870–9 (10 years),	6·65	14·79	16·95	22·14	28·17	52·01
1874–83 (10 years),	7·70	15·10	14·75	19·35	21·25	43·42
1884,	4·11	15·20	11·56	11·00	12·58	13·95

If these numbers are compared with those of men serving at home, it will be seen that the mortality at every period is greater in India. If the average for the corresponding years in England be multiplied by three for the earlier ages and by two for the older, the result comes close to the average Indian numbers. At the ages above 30 the rate in India is distinctly diminishing.

These facts are an argument against the view that age, *per se*, increases the total mortality faster than it does at home; and the statistics of officers confirm the inference drawn from the argument. The mortality of the members of the Military and Medical Funds in Madras and Bengal has been carefully determined by actuaries, and the following table proves that

[1] *Army Medical Reports*, vol. xxvi.

mortality among officers does not increase with age in anything like the proportion it does among non-commissioned officers and privates. The large mortality in the earlier ages is owing to the statistics running back to long periods, when the deaths were more numerous.

Mortality in Officers (in Service Fund) according to Age,[1] *per* 1000 *of respective Ages.*

	Under 20.	20–25.	25–30.	30–35.	35–40.	40–45.
Madras Military Fund, 1808–1857, . . .	29	32·6	31·6	32	29·4	28·4
Bengal Military Fund, .	12	22·3	24·5	27·5	29	28·9
Madras Medical Fund, 1807–1866, . . .	...	14·2	35·1	34·1	33·4	34·1

The mortality among officers of 30 to 35 years of age was, therefore, nearly the same as among privates, but at 35 to 45 it was very much less. Mere climatic conditions, acting more and more as age advances, can therefore not account for the greater mortality of the private soldier, for they would act equally on the officer. No doubt the officer had a more frequent furlough to England; but would this be capable of giving him such an advantage? We must conclude that other conditions apart from, or at any rate superadded to, climate, must have given rise to the larger mortality of the private soldiers.

Mortality according to Service.

The question can be further considered by taking into account the effect of service. The following table from Dr Bryden shows the effect of service for three years at the different ages :—

Death-rate per 1000 *in the European Army of Bengal, excluding Cholera.*

	Under 20 years of age.	20–24.	25–29.	30 and over.
Whole army of 1865–70, . .	7·61	13·67	17·41	29·94
First year of service, . . .	12·93	24·87	39·32	47·08
Second year of service, . .	3·95	15·84	23·08	35·61
Third year of service, . . .	2·87	9·92	17·64	27·77

This table brings out very forcibly the great mortality of the first year of service at all ages; the older men suffer as much as the younger; the mortality falls during the second year of service, and in the third is below the mean mortality of the army at large. To determine how far this is owing to climate, we must analyse the causes of this mortality. The careful statistics of Dr Bryden enable us to answer this point with some accuracy.[2]

[1] Copied from the *Report for* 1871 *of the Sanitary Commissioner* (Dr Cornish) *for Madras*, 1872, p. 7.

[2] See Appendix C, in *Bengal Sanitary Report* for 1870, p. 255 *et seq.*, and for 1871, p. 213; also *Vital Statistics of India*, vol. v. Dr Bryden's statistics, as given in the Reports of the Sanitary Commissioner with the Government of India, and in the separate Blue Books (*Vital Statistics of the Bengal Presidency*, 1870 and 1878), are so much more complete than any other that they have rendered obsolete all the older records. Dr Cornish's statistics, as contained in the *Madras Sanitary Reports*, are also most valuable.

Deaths in the first Two Years of Indian Service and the Death-rates at different Ages (1871–75).[1]

Causes of Death.	Died per 1000 of Strength in the Biennial Period.			
	Under 24.[2]	25–29.	30–34.	35 and upwards.
Cholera, ...	5·34	5·87	4·77	13·86
Remittent and continued fevers, .	2·10	3·84	1·27	3·73
Enteric fever, ...	9·77	10·16	1·59	0·53
Apoplexy, ...	2·11	2·71	4·77	12·26
Dysentery and diarrhœa, . .	1·80	3·39	3·82	11·20
Hepatitis, ...	1·88	5·42	4·45	12·26
Phthisis pulmonalis, . . .	2·10	1·58	3·82	8·53
Heart diseases, ...	0·15	2·26	3·82	9·06
All other causes, ...	6·00	7·00	8·27	22·39
All causes, ...	31·25	42·23	36·58	93·82
All causes, excluding cholera,	25·91	36·36	31·81	79·96

100 *Deaths made up at different Periods of Residence in India* (1871–76).[3]

Disease.	1st Year.	2nd Year.	In first four Years.	5th, 6th, and 7th Years.	Above the 7th Year.	Above the 10th Year.
Enteric fever, ...	32·9	16·8	22·2	5·2	0·9	0·5
Hepatitis, ...	10·1	17·6	14·0	18·9	16·0	15·7
Heat-apoplexy, . .	12·7	9·7	11·8	11·9	10·3	9·5
Phthisis, ...	7·7	10·9	9·0	8·1	8·2	7·8
Dysentery, ...	9·6	10·4	9·0	10·1	13·3	13·7
Other fevers, ...	8·9	8·3	7·8	7·3	6·0	4·6
Heart disease, . .	5·3	7·5	5·8	11·2	16·2	17·6
Respiratory diseases, .	4·1	4·1	4·4	5·9	6·8	6·6
Suicidal deaths, . .	1·2	3·7	2·1	6·1	5·2	6·1
All other causes (excluding cholera, smallpox, and accidents), . . .	7·5	11·0	13·9	15·3	17·1	17·9
Total, . . .	100	100	100	100	100	100

These tables are instructive on several points:—

1. As regards *Fever:* the most serious mortality is from *enteric* fever, which attacks the young soldier, especially in his earliest term of service. The mean mortality below 30 years of age is, in round numbers, 10 per 1000 of strength, from 30 to 35 less than *one-sixth* of that proportion, and above 35 only *one-thirtieth.* With reference to length of service, the first year in India shows that about 33 per cent. of the total deaths are due to enteric fever, and in the first *four* years 22 per cent.; from the fifth to the seventh the proportion is reduced to 5 per cent., whilst after seven years it is merely fractional. The other fevers show much less difference.

2. *Heat-Apoplexy.*—This formidable disease is most severe in the earlier years, and attacks especially the *old* soldier: the mortality above 35 years of age is 12½ per 1000, *six* times the ratio below 24, and *five* times that below 30.

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[1] *Vital Statistics of India* (Bryden), 1878, vol. v. p. 56.
[2] The number of soldiers under 20 is now very small—little over 2 per cent.
[3] From Bryden's *Vital Statistics of India*, vol. v., 1878.

3. *Dysentery* and *diarrhœa* are more fatal to old soldiers, and in the later years of service.

4. The same is very markedly the case with *hepatitis*, which is markedly a disease of deterioration.

5. *Phthisis* is rather more fatal in the earliest years of service, but (in the period 1871–75) shows most mortality among the older soldiers. This, however, does not appear to be uniformly the case, if we compare previous years.

6. *Heart* diseases show, as might be expected, an increasing mortality with age and length of residence in India.

The most dangerous disease, therefore, which young newly arrived soldiers have to face in India is (putting aside *cholera* for the present) *enteric fever*; next to that, but at a considerable distance, *dysentery* and *diarrhœa*. These diseases, but most especially enteric fever, are so completely under the control of sanitary measures that their continuance is a slur upon the application of our sanitary knowledge. There is no reason to believe that proper preventive means should be less successful in India than at home. For old soldiers, that is, men over 30 years of age, newly arrived in India, the diseases to be feared are *heat-apoplexy*, *dysentery*, *hepatitis*, and *heart disease*, all diseases of deterioration, and favoured and aggravated by intemperate habits. With careful medical selection of men much might be prevented, and hygienic precautions, such as free ventilation against heat-apoplexy, might do a great deal towards a diminution of the mortality. But drinking habits are the most dangerous enemy the soldier, particularly as he advances in years, has to contend with. The abolition of the sale of spirits to European soldiers, either in canteens or elsewhere, would be a great advantage.

Troops should be stationed in the hills as much as possible, so as to remove them from the influences of excessive heat, malaria, and choleraic poison, and also it might be hoped to some extent from enteric fevers. More efforts ought to be made to provide employment and recreation for the troops, who suffer greatly from enforced idleness, ennui, and the foul air of their barrack-rooms, to which they are still too much confined for fear of exposure to the sun. Undue exposure is unadvisable, but it may be safely said that its consequences are smaller evils than those undoubtedly arising from the mistaken steps taken for their prevention.

The men ought also to be spared as much as possible from unnecessary night duty.

As regards age of arrival in India, men cannot now be sent out under 20 years of age, for, as they are not taken into the army before 19, their preliminary training will not be over before that age: there is also now an order against it. Above that age the younger they go the better. For the first years, if protected from enteric fever, cholera, and dysentery (which is quite possible), their health will be as good, if not better, than at home. It seems pretty clear, on the other hand, that men ought not to remain beyond 30 years of age, if possible, unless they are non-commissioned officers: the best period would appear to be between 21 and 28 years. After 30 years of age the private soldier is an old man in India (Bryden, Roberts), and this is partly due to the work he has had to do (particularly night guards—Roberts), but also very largely to habits of drinking. When we find, as in the army of Bengal, 30,000 men yielding 10,000 cases of drunkenness in the year, we cannot but consider it a deplorable condition of things, knowing as we do what a large amount of unrecorded excess this represents.

Cholera in the Bengal Presidency.[1]

During fifty years (from 1818 to 1867) the mean annual mortality from cholera per 1000 of European strength in Bengal was no less than 9·4. It was the great cause of variation in the percentage of mortality from year to year. The cholera mortality was not owing, as might have been supposed, to service in the stations in Bengal proper (the so-called endemic home of the cholera), for the mean mortality in Bengal proper was below that of the Panjāb, where cholera is occasional, *i.e*, prevails only at certain seasons and in certain years. If we compare Bengal proper with two other military districts, Agra (with Central India) and the Panjāb, two facts come out very clearly—(1) that in Bengal proper the mortality is more steady, but on an average of years is lower than in the other two districts, where the mean mortality is heightened by occasional tremendous outbreaks unknown in cholera's endemic home; (2) that in Bengal proper the Sepoy mortality is higher than in Europeans, while in the other stations it is much lower.[2]

Table to show the Mortality from Cholera per 1000 *of Strength in Europeans and Sepoys.*

Year.	Bengal Proper.		Agra and Central India.		Panjāb.	
	Europeans.	Sepoys.	Europeans.	Sepoys.	Europeans.	Sepoys.
1861, . . .	6·51	6·38	41·21	0·25	36·10	6·88
1862, . . .	6·11	5·44	26·90	1·30	12 74	3·99
1863, . . .	3·17	4·25	3·82	0·40	0·13	0·90
1864, . . .	2·50	6·40	0·62	...	0·06	0·09
1865, . . .	6·40	9·20	7·20	3·10	0·14	...
1866, . . .	1·90	7·03	0·23	...	...	...
1867, . . .	2·50	3·50	3·30	0·90	20·70	3·90
1868, . . .	5·34	2·51	3·36	0·16	...	...
1869, . . .	0·53	4·43	30·18	7·25	16·86	7·33
1870, . . .	1·00	3·03	0·47	...	...	...
1871, . . .	0·51	1·25	0·24	...	...	...
1872, . . .	1·01	2·70	4·75	...	13·86	2·80
1873, . . .	0·53	2·76	0·97	1·05	...	...
1874, . . .	0·50	4·74	...	0·26	0·09	0·07
1875, . . .	...	2·76	5·57	1·57	2·27	1·50
1876, . . .	2·49	2·01	0·25	...	4·48	1·80
Means, . .	2·12	4·27	7·46	1·01	5·63	1·83

This table is most instructive, and proves beyond doubt that while cholera has never (until lately) been absent from Europeans in Bengal proper[3] (the endemic home), it has never attained the destructive prevalence

[1] The statistics referred to in this section are those given by Bryden in his valuable Reports (*Vital Statistics of the Bengal Presidency*, 1870 and 1878), and Appendices from Dr Cuningham's Annual Report.

[2] It has been wrongly stated that the excessive mortality from cholera of Europeans in the Bengal Presidency is an effect of race; the statistics of Bengal proper (as shown in the next table) and of the Madras Presidency entirely disprove this. In the Madras Presidency, in 1860–66, the annual European cholera mortality was 3·1 per 1000 of strength, and the Sepoy mortality was 3·07, or virtually the same.

[3] Since 1876 the ratio of deaths from cholera among European troops has been very small in the Presidency division (including Bengal proper):—

1877, ...	0·49	per 1000.
1878, ...	0·97	,,
1879, ...	nil.	,,
1880, ...	nil.	,,
1881, ...	2·08	,,
1882, ...	0·47	,,
1883, ...	0·48	,,
1884, ...	0·94	,,

which occurs in Central India and the Panjāb, where it is sometimes entirely absent for years, and yet the severity of the outbreak, where it does occur, makes the mean Panjāb and Central India cholera mortality of sixteen years far greater than the cholera mortality of Bengal proper.

Among Sepoys the mortality in Bengal proper is actually greater than in Europeans, while it is far less in the Upper Provinces, and in some outbreaks (as in Central India in 1861) the Europeans have suffered frightfully, while the Sepoys have been scarcely touched.

What, then, is the cause that, while in Bengal proper, where the conditions of cholera always exist, the mortality should be comparatively low, there should be such terrible outbreaks in up-country stations where cholera is only a visitor, and why should these outbreaks affect the Europeans so particularly? To answer this question we may select a few of the worst stations in Upper India, and see what the mortality was in the epidemics of 1861–2–7–9–72–5–6.

Mortality per 1000 *of European Strength in different Epidemics.*

	1861.	1862.	1867.	1869.	1872.	1875.	1876.
Meerut, . .	34·32	15·70	70·30	7·04	32·62	7·35	...
Mean Meer, .	245·63	49·93	50·49	...	86·87	1·90	...
Peshāwar, . .	...	49·24	92·93	120·14	21·53	...	23·06
Agra, . .	56·56	42·50	...	...	15·57	...	...
Morar, . .	137·43	37·25	11·52	82·89	17·05	17·05	...

This table shows that the outbreaks are very variable in intensity; a station may be quite free from cholera in one epidemic and suffer frightfully in another. In Agra, in 1861–62, there were seven outbreaks; in 1867 and 1869 there was no case, though the disease was all round.

If we analyse the station statistics themselves, the remarkable fact comes out that some of the severest outbreaks involved only a portion of the Europeans.

At Meerut, in 1867, while the 3rd Buffs were literally more than decimated, the hussars and Sepoys were as healthy as if they had been in England.

These facts show that the hypothesis of an epidemic influence produced by something floating in the air is incredible, and for such a partial distribution as is shown above would be impossible. If these figures prove anything, it is that the cause of the tremendous loss in these stations is not a generally diffused cause, but a well-marked local development, having narrow limits, and sometimes involving only a single barrack.

The figures also show that the supposition that the difference in mortality between the Europeans and Sepoys is owing to difference of social habits (especially as regards latrine arrangements) is unlikely, for different bodies of Europeans in the same station suffer as diversely as Europeans and Sepoys.

The localising conditions, which give the intense spread to what is, no doubt, an imported agent, must be referable to either soil, water, air, or food. Faulty latrine arrangements, if they exist, must act through one or other of these media, poisoning the ground, or air, or water. The inquiry into the local spread of cholera, if concentrated on the locality, and carried to the exhaustion of every possible factor, must surely solve this problem. It is as in enteric fever at home, where everything often seems a mystery until a minute search is made, and then what seemed inexplicable is found to be simple.

But, without waiting for the solution of the cause of these localisations of cholera, the fact of the localisation points out preventive measures which, as a matter of reasonable precaution, ought to be taken in every barrack in Upper India where these great outbreaks have occurred. These measures should be adopted on the ground of removing every possible local cause, even though the particular precaution may not have been *proved* to be necessary.

1. The influence of the ground should be excluded by the most thorough paving and cementing everywhere, and by careful examination and cleansing under every floor. When possible ground floors should not be occupied as sleeping rooms.

2. A fresh water supply should be obtained at any cost, be from an undoubted source, and be kept solely for the use of the barrack. During an epidemic all water should be boiled before use, or, better still, distilled.

3. The cooking arrangements should be entirely remodelled, and the supply of every article of food carefully considered.

4. The latrine arrangements should be remodelled, the places changed, and the system at every point scrutinised to see if soil, air, or water can in any way be contaminated by percolation or emanation.

If, after adopting these measures, and carrying them out fairly in their integrity, an outbreak still occurs, this cannot throw doubt on the correctness of the view which attaches so much weight to localisation; it will only show that we have not solved the problem of the localising agency, and if no other local sanitary measures can be adopted the barrack should altogether be abandoned. But this will hardly be found to be necessary.

With regard to Mean Meer, which has suffered so severely and so often from cholera, it is a very important fact that enteric fever has from time to time prevailed at that station, as in 1860–69–70. In the two latter years a careful examination of the water supply was made by Surgeon-Major Skeen, of the 85th Regiment, who formally gave evidence on the point that in both these years the water was the medium of introduction. The fact of enteric fever being thus introduced by well water (temporarily used in the absence of canal water), the chemical analysis showing fæcal impregnation of this well water, and the existence of sources of fæcal contamination of water, all seem strongly to indicate that cholera evacuations would also, in all probability, pass into the water, and might account for the fearful outbreaks at Mean Meer. At any rate, there can be no doubt that means should be taken to entirely close the wells, which are occasionally used, and if the canal water which is ordinarily used does not give a sufficient supply at all times of the year, that a fresh source should be brought down at any cost. The strong facts given by Dr De Renzy respecting Peshāwar prove that the same course should be adopted in that station. These measures are imperatively demanded as a matter of precaution, and no theoretical arguments that the water is not to blame ought to be allowed to override them. The diminution of cholera at Calcutta among Europeans since the introduction of a pure water supply and improved drainage is very encouraging for the strenuous application of local measures.

Phthisis in India.

The amount of phthisis in India is a highly interesting question, and in the following table the admissions, deaths, and invaliding from this cause are given for successive periods:—

Phthisis, including Hæmoptysis per 1000 of Strength.

	Admissions.	Deaths.	Invalided.[1]	Total Deaths & Invalided.[1]
BENGAL.				
4 years—(1863-66),	7·5	1·71	2·73	4·44
4 years—(1867-70),	10·1	1·75	3·64	5·39
6 years—(1869-74),	10·1	1·87	...	...
6 years—(1875-80),	7·8	1·48	...	...
BOMBAY.				
4 years—(1863-66),	7·7	1·52	3·28	4·81
4 years—(1867-70),	9·2	1·23	3·58	4·81
6 years—(1869-74),	10·0	1·67	...	...
6 years—(1875-80),	6·7	1·25	...	...
MADRAS.				
4 years—(1863-66),	11·5	1·46	3·66	5·11
4 years—(1867-70),	11·9	1·34	4·74	6·07
6 years—(1869-74),	13·0	1·62	...	...
6 years—(1875-80),	8·1	1·37	...	...
Means, 18 years (1863-80),			...	...
Bengal,	8·7	1·68	2·97	4·64
Bombay,	8·2	1·40	3·74	5·08
Madras,	10·8	1·44	3·73	5·02
1884, Bengal,	7·2	1·09	2·64	3·73
Madras,	5·4	0·55	2·31	2·86
Bombay,	8·1	1·03	3·26	4·29
1884, India generally,	7·0	0·97	2·68	3·65

How regularly the causes of phthisis must be acting is seen in the fact that in four years, 1863-66, 74 men died from phthisis in the Bombay Presidency, and 73 in the Madras Presidency, the mean number of troops being in each case almost precisely the same (12,119 and 12,512). In the next four years, with a smaller number of troops, 53 and 55 died in the two Presidencies. The means of deaths (for 18 years) and invaliding (12 years) are practically identical for Madras and Bombay as shown above. In the Bengal Presidency the deaths are higher, but the invaliding is less, so that the slight difference is compensated. More men died, and fewer were sent away.

The table seems to show clearly that the immense range and variation of climates in which the troops serve in India produce no effect whatever on the production of phthisis; and this inference is again strengthened by the fact that the mortality in Bengal from phthisis is precisely the same as in Canada (1·71 per 1000). The means for 12 years (1869-1880) were—Bengal, 1·37; all India, 1·30; Canada, 1·37.

If the Indian mortality and invaliding are compared with the table already given of phthisis in the home army, it will be seen that there is decidedly less phthisis in India. The mortality is less, and the invaliding is far below. There can be no doubt, then, that the causes of phthisis are less active in India than at home; and if these causes are not climatic, must the difference not be found in the larger breathing space and greater lateral separation men have in India?

It would be interesting to have some certain statistics of the amount of phthisis in former years, when men were more crowded; Ewart[2] gives the deaths in the Bengal Presidency, from 1812 to 1831, as 2·6 per 1000 of strength, and from 1832 to 1851-52 as 1·8 per 1000. In the Bombay

[1] 1871-74 and 1877-88 omitted.
[2] *Vital Statistics of the Armies in India*, 1859, p. 164.

Presidency, from 1803 to 1827, they were 1·6, and from 1828 to 1852, 1·4 per 1000. Ewart thinks this indicates a large decrease, but doubts whether this may not be owing to more accurate diagnosis. The table just given shows, however, that in Bombay at any rate the deaths in the years 1863–80 were as great as in 1828–52. In Bengal there is a diminution, but it is very slight. In the early period, however, there may have been less invaliding. In the absence of reliable statistics, the question of the relative amount of phthisis now and formerly seems impossible to be answered.

With respect to the cure and prevention of phthisis, it seems a great pity to send phthisical invalids to England, where they die at Netley, or are cast out to die miserably among the civil population, when in the Himalayas there are elevated localities which must be particularly adapted for the successful treatment of consumption. When means of communication are improved, it is possible that we may see phthisical invalids going from Europe to the high peaks of the Himalayas, and why should not the European soldier, who is actually in India, benefit by the mountain ranges? A phthisical sanitarium, at an altitude of 10,000 feet, would be likely to cure the disease in many cases, if it were diagnosed early, and then if the men were afterwards kept on the lower hill stations, they would probably become perfectly strong. To send these men home to England is condemning them to almost certain death. Formerly the distance in India would have been fatal to such a plan, but now, by proper arrangements, even weakly men could be brought from all parts of India. Dr Hermann Weber, who has paid great attention to the effect of altitude on phthisis, holds very decided views as to the beneficial effect of such an arrangement, and has already urged this point on the attention of the authorities.

The other diseases of the lungs are not unknown in India. Pneumonia gives a mortality in Bengal of about 0·5 per 1000 of strength, or a little less than at home (=0·571); while in the other two presidencies it is not half this amount. Acute bronchitis also causes in all the presidencies a mortality almost precisely the same as at home (0·27 and 0·285 per 1000).

Loss of Service—European Troops.

The admissions have been already given. The mean daily sick (1874–83) are :—

		1884.
Bengal,	63·51	70·86
Madras,	58·16	59·14
Bombay,	60·19	64·70
All India,	61·78	66·07

As compared with home service, a larger number of admissions, a greater daily number of sick, and a shorter duration of cases and a larger mortality indicate not only more sickness, but the presence of very rapid mortal diseases, which shorten the mean duration of all cases.

The chief causes of admissions are "paroxysmal and continued fevers," venereal disease, dysentery, rheumatism, integumentary diseases, and digestive affections (not hepatitis). Hepatitis and cholera cause few admissions, but a large mortality.

It is most satisfactory to find that the sickness and mortality are both rapidly falling, owing to the energetic means now being adopted by the

Government and to the increased sanitary powers and improved curative means of the medical officers.

The prevalence of venereal disease demands as much attention in India as in England, but the preventive measures will be much easier. Police regulations and proper surveillance are now being enforced, and Lock hospitals are established in many places.

Invaliding of European Troops.

For some years the invaliding statistics of Bengal were given with great care by the late Dr Bryden.[1] The invaliding ratio, from all causes, in the Bengal European army varied in ten years (1861–70) from 28·09 to 53·98 per 1000 of strength, the mean being 38·9; and in the next ten years (1871–80) from 29·88 to 47·14, the mean being 40·6.

In the Bengal army the ratios were, per 1000 strength—

Years.	Under 25.	25 to 30.	30 and upwards.
1865–70, . .	26·55	39·74	78·34
1871–75, . .	24·60	35·92	58·17

Army of India.

Years.	Under 25.	25 to 34.	35 and upwards.
1871–75, . .	25·84	37·07	91·34

Bryden remarked that there was but little change in the invaliding rate from 25 to 34 years of age, and he therefore put the ten years in one class.

The invaliding was high during the early years of service, as shown by the following table:—

Invaliding per cent. of the total Invaliding at the different Periods of Indian Service, 1871–75.

1st and 2nd years, . .	28·5	1–4	48·1
3rd and 4th „ . .	22·3		
		5–7	23·2
		above 7	28·7
			100·0

The chief causes of invaliding were phthisis, heart affections, hepatitis, and general debility, and the following table, calculated from Bryden, shows the ratio of these classes (1871–5):—

Chief Causes for Invaliding.	1 to 4 Years.	5 to 7 Years.	Above 7 Years.
Phthisis, ...	11	9	6
Heart affections, . . .	15	10	6
Hepatitis, ...	15	17	16
General debility, . .	15	20	29
Per cent. of total invaliding at each period, . .	56	56	57

The total invaliding is made up of those sent home for discharge and for change of air. From about 30 to 60 per cent. of all invalids are in the latter category. In the ten years 1870–79 the mean number of invalids sent home

[1] *Vital Statistics of the Bengal Presidency*, 1870 and 1878; and *Reports of the Sanitary Commissioner* (Dr Cuningham) *with the Government of India*. Reference must be made to these elaborate reports for the full details.

was 42·44, and those finally discharged were 16·08 per 1000 of strength. Those sent home for change were thus 62 per cent. of the whole. In 1880 29·88 per 1000 were sent home and 21·40 discharged, the percentage sent home for change being thus only 28½. In 1884 the total sent home were 31·9 per 1000 and 14·30 discharged, 55 per cent. of the whole being sent home for change.

Mortality of Native Troops.

Colonel Sykes gave the mortality for 1825–44 as 18 per 1000 of strength for all India; and for Bengal, 17·9; Bombay, 12·9; Madras, 20·95.

In Madras, from 1842 to 1858, the average was 18 per 1000 (Macpherson), of which 6 per 1000 each year were deaths from cholera.

Ewart gives the following numbers per 1000 of strength—Bengal (1826–1852), 13·9; Bombay (1803–54), 15·8; Madras (1827-52), 17·5.

Taking successive quinquennial periods, there has been a slight progressive decrease in mortality, but this is less marked than in Europeans.

The excess of mortality is chiefly due to cholera, dysentery, and fever.

In Bengal, in the years 1861–67, the annual mortality per 1000 of men present with the regiments was 14·57. In Madras the average mortality in six years, 1860–66, was 12·6.

The following table gives the mortality of native troops per 1000 of strength for the period 1867–76, from Bryden's tables :—

Mortality of Sepoys (1867–76) *per* 1000 *of Strength.*

Diseases.	Bengal.
Cholera,	2·12
Fevers,	2·84
Heat-apoplexy,	0·22
Dysentery and diarrhœa,	2·01
Hepatitis,	0·15
Spleen diseases,	0·28
Respiratory diseases,	2·57
Heart disease,	0·20
Phthisis pulmonalis,	0·77
Dropsy,	0·09
Scurvy,	0·14
Atrophy and anæmia,	0·52
All other causes,	1·19
Violent deaths,	0·74
Total deaths,	13·84
Deaths, excluding cholera,	11·72
Total deaths, including those in absence,	17·25

SECTION IX.

CHINA.

Hong-Kong.

Although the English have occupied Canton, Tientsin in the north, and several other places, yet, as their occupation has been only temporary, it seems unnecessary to describe any other station than Hong-Kong.

Garrison of Hong-Kong about 1000, but differing considerably according to the state of affairs in China.

The island is 27 miles in circumference, 10 long, and 8 broad at its widest part.

Geology.—The hills are for the most part of granite and syenite, more or less weathered. In some parts it is disintegrated to a great extent, and clayey beds (laterite) are formed, in which granite boulders may be embedded. Victoria, the chief town, stands on this disintegrated granite. As in all other cases, this weathered and clayey granite is said to be very absorbent of water, and, especially in the wet season, is considered very unhealthy.

Climate.—Mean annual temperature, 73° Fahr.; hottest month (July), 86°·25; coldest month (January), 52°·75; amplitude of the yearly fluctuations, 33°·5.

The humidity is considerable,—about 80 per cent. of saturation as an average.

The N.E. monsoon blows from November to April; it is cold, dry, and is usually considered healthy and bracing; but if persons who have suffered from malaria are much exposed to it, it reinduces the paroxysm. The S.W. monsoon blows from May to October; it is hot and damp, and is considered enervating and relaxing. The difference in the thermometer between the two monsoons has been said to be as much as 46°, but this seems excessive.

The rainfall is about 90 to 100 inches with the S.W. monsoon.

In addition to Victoria, there are two or three other stations which have been occupied as sanitaria, viz., Stanley, seated on a peninsula on the south end of the island, and about 100 feet above the sea; and Sarivan, 5 miles east of Victoria. Neither station seems to have answered; the barracks are very bad at Stanley, and are exposed too much to the N.E. monsoon, which, at certain times, is cold and wintry; during the S.W. monsoon it is healthy. Sarivan has always been unhealthy, probably from the neighbourhood of rice fields. Since the close of the last war a portion of the mainland, Cowloon, opposite Victoria, has been ceded, and has been occupied by troops. It is said not to be, however, even so healthy as Hong-Kong,[1] but there are differences of opinion on this point.

Hong-Kong has never, it is said, been considered healthy by the Chinese. The chief causes of unhealthiness appear to be the moist laterite and weathered granite, and the numerous rice fields. Indeed, to the latter cause is ascribed by some (Smart[2]) the great unhealthiness, especially when the rice fields are drying in October, November, and December.

Local causes of unhealthiness existed till very lately in Victoria. In building the barracks the felspar clay was too much cut into, and, in addition, the access of air was impeded by the proximity of the hills. The S.W. monsoon was entirely shut out. Till lately sewerage was very defective.

Owing probably to these climatic and local causes, for many years after its occupation in 1842 Hong-Kong was excessively unhealthy. Malarious fevers were extremely common, and not only so, but it is now known that enteric fever has always prevailed there (Becher and Smart). Dysentery has been extremely severe, and has assumed the peculiar form of lientery. This was noticed in the first China war, and appears, more or less, to have continued since. In addition to these diseases, phthisis appears to have been frequent.

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[1] See Report of Surgeon Snell, *Army Medical Report*, vol. v. p. 360, for the causes of the unhealthiness of Cowloon.

[2] *Transactions of the Epid. Soc.*, vol. i. p. 191. This paper should be consulted for an excellent account of Hong-Kong, and of the diseases among sailors especially.

For some years there were such frequent wars in China that the exact amount of sickness and mortality due to the climate of Hong-Kong could not be well determined. But it is becoming much healthier than in former years, owing to the gradual improvement in sanitary matters which goes on from year to year. In 1865 there was, however, much sickness, owing apparently to overcrowding and to bad accommodation.

In the Statistical Reports, the troops serving in Hong-Kong, Cowloon, Canton, Shanghai, and the Straits Settlements are classed together, so that the influence of Hong-Kong *per se* can only be partially known.

In the years 1859–66, which include years of war, the admissions in South China averaged 2131, and the deaths 56·25, or, exclusive of violent deaths, 52·63 per 1000 of strength, and there was in addition a large invaliding. Paroxysmal fevers gave 609 admissions and 7·77 deaths; continued fevers, 25·25 admissions and 4·17 deaths; and dysentery and diarrhœa, 249 admissions and 16·3 deaths per 1000. In later years the mortality was less; in 1869–70 it was 16·02, and in 1871 only 5·82 per 1000 of strength, and of these only 3·88 was from disease. In the five years 1871–5 it was 11·73; and in 1876–80 it was 8·61, giving for the ten years a mean of 10·17. This contrasts very favourably with the mean of the previous ten years (1861–70), which was 39·84, or nearly *four* times as great. In 1884 the admissions were, at Hong-Kong, 859·7 per 1000, deaths 8·47, invalided 44·26, average daily sick 44·84. In the Straits Settlements, admissions 1117·7, deaths 5·4, invalided 31·32, average daily sick 49·23 per 1000. The death-rate of the two stations taken together was 7·04, of which only 5·43 were from disease. The mean of five years (1879–83) was 7·59, of which 6·71 were from disease. It is evident that the causes of sickness and mortality are now being brought under control.

SECTION X.

EGYPT.

We have now a garrison of 6,468 men (in 1884) in this country. The climate is very dry, subtropical in Egypt proper, but with increasing temperature as the Nile is ascended. Mean temperature at Abbasich (near Cairo) in 1884 was 69°·9 F.; mean maximum 77°·6, mean minimum 58°·9; absolute maximum 112°·6 in June, absolute minimum 43°·7 in March. Rain for the year 2·35 inches, number of rainy days 11; relative humidity 57·1 per cent.; maximum humidity 73 in January, minimum 43 in April; mean barometer 29·895. The admissions in 1884 were 1266·2 per 1000, and the deaths 11·59, of which 8·81 were from disease, the rest being violent deaths. The most numerous admissions were from syphilis (primary) 229·4, (secondary) 37·1; digestive system (including diarrhœa, dysentery, liver disease, &c.) 206·9; continued fever 156·8. The chief cause of death was enteric fever, 4·95 out of 8·81 from disease, or 57 per cent. of all deaths. In 1883 the death-rate was 34·82, but 17·60 of this was due to cholera; the death-rate, therefore, omitting cholera, was 17·22, or, omitting violent deaths (2·16), it was 15·06; of this, 6·33, or 42 per cent., were due to enteric fever. Diseases of the eye, for which Egypt had formerly such a bad name, are numerous (in 1884 they were 52·6 per 1000, against 14·7 at home), but, considering their prevalence among the native population, it is perhaps surprising there are not more. None have been very serious, for out of 340 cases 90 per cent. were simple

conjunctivitis, and only 1 case of purulent ophthalmia is recorded. It is clear that, with ordinary hygienic precautions, Egypt is a healthy station. Enteric fever, quite preventible, is (in 1884) responsible for 32 deaths out of 74;[1] sunstroke, due to the imprudence of the men themselves, 4 deaths; 1 fatal case of small-pox, pneumonia 2, pleurisy 1, œdema of glottis 1, abscess of larynx 1, phthisis 2, heart disease 3, dysentery 2, hepatic abscess 3, acute atrophy of liver 1, recto-vesical fistula (result of injury) 1, prostatic abscess 1, poisons 2 (alcoholic), injuries 11, killed in action 5. There is hardly one of those cases that is not preventible, and that might not have occurred at home.[2]

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[1] 75 including the death of 1 invalid.

[2] *Australia and New Zealand.*—The withdrawal of the troops from these colonies renders it unnecessary to give any statistical details.

CHAPTER V.

SERVICE ON BOARD SHIP.[1]

SERVICE on board ship must be divided into three sections, corresponding to three different kinds of service.

1. Transport ships, for the conveyance of healthy soldiers, their wives and children, from place to plaee, or for conveying small parties of troops in charge of convicts.

2. Transports for conveyance of siek from an army in the field to an hospital in rear, or from a foreign station to a sanitarium, or home. Although the term is a little odd, it is convenient to eall these ships Sick Transports.

3. Hospital ships, intended for the reeeption and treatment of the sick.

SECTION I.

TRANSPORTS FOR HEALTHY TROOPS.[2]

The use of Government transports has very much altered the duty of medical offieers on board. The transports are really men-of-war, *i.e.*, officered by the Royal Navy, and under naval regulations. The medical officer of troops has therefore nothing to do with the vessel and its arrangements. If hired transports are used, the *Queen's Regulations* (1885) (section 17, Movement of Troops by Sea) and the *Medical Regulations* (part i. section iii. sub-section iii. paras. 83–107; part vi. section vii. paras. 1110–1122) have to be earried out.

SECTION II.

TRANSPORTS FOR SICK TROOPS.

No speeifie regulations are laid down with respect to these hired ships, but it would be very desirable to have some set rules with respect to space, diet, and fittings. Invalids are now carried from India and the Colonies in Government transports; occasionally hired transports are used. At present the diet of invalids on board the hired transports is not good. In respect of fittings, the use of swinging cots for feeble men, and well-arranged closets for dysenterie cases, are very important. So also with the cooking; the

[1] See Rattray's paper read to the Medico-Chirurgical Society in 1872; also the 5th edition of this work; and *Naval Hygiene*, by Professor Macdonald, R.N., M.D., F.R.S. (Smith, Elder & Co.), 1881.

[2] The following note is given in the *Queen's Regulations*, 1885, section xvii. para. 1 (*note*):—"*A Troop-Ship* is one of Her Majesty's ships commissioned as a troop-ship. *A Transport* is a private ship wholly engaged for the Government service on monthly hire, or one wholly engaged by the Government to execute a special troop service, though not hired by the month. *A Troop Freight Ship* is a ship in which conveyance is engaged by Government for troops, but which is not wholly at the disposal of the Government."

coarse ship cooking is a great trial to many patients. If there is need of Government transports for healthy men, the necessity is still greater for sick men.

As far as possible, the sick should be treated on deck in fine weather, a good awning and a comfortable part of the deck being appropriated to them. It would be a good plan not to send home officers and sick men in the same ship, but to have officers' ships, so as to give up the poop to the men in the ships which carried them. This division would be a gain to both.

In time of war, sick transports are largely used to carry troops to hospitals in rear. For this purpose good roomy steamers must be chosen. For economy's sake they will generally be large, and probably with two decks; they should never have more, and indeed a single deck is better. But if with two decks, each space should be separately ventilated by tubes, so as, as far as possible, to prevent passage of foul air from the lower to the upper deck. All the worst cases should be on the upper deck, especially surgical cases.

The decks of these vessels should be as clear as possible, so that men can be treated on deck. An apparatus should be arranged for hoisting men on deck from below.

It has been proposed to fit these ships with iron bedsteads, and no doubt this gives the men more space; but a better plan still would probably be to have short iron rods, to which every cot could be suspended. The sick men might be carried in their cots on board, and again removed. If the rods are made about 14 inches high, and bent in at the top so as to form a hook, a cot is hung easily, and will swing. There is space enough below to put a close-stool or pan under the man without stirring him, if a flap is left open in the canvass, and a hole left in the thin mattress.

Fixed berths are not so good, but some must be provided. Some cots can swing from the top, and some men can be in hammocks. Probably every sick transport should have all these, viz., iron bedsteads at some points fastened to the deck, iron standards for swinging cots, cots swinging from the roof, low berths, and hammocks.

In these sick transports the kits and clothes must be stowed away; and as they are often very dirty and offensive, and sometimes carry the poison of typhus and other diseases, the place where they are put should be constantly fumigated with nitrous and sulphurous acid alternately. Robert Jackson mentions that dirty clothes and bedding may be soon washed sweet by mixing oatmeal with salt water.

Directly a sick transport has landed the sick, the whole place should be thoroughly washed and scraped, then the walls and ceiling should be lime-washed, and the between-decks constantly fumigated till the very moment when fresh sick embark.

SECTION III.

HOSPITAL SHIPS.

These are ships intended for the reception and treatment of the sick,—floating hospitals, in short. Whenever operations are undertaken along a seaboard, and especially when a force is moving, and places for fixed hospitals cannot be assigned, they are indispensable. They at once relieve the army from a very heavy encumbrance, and, by prompt attendance which can be given to the sick, save many lives. They should always be

organised at the commencement of a campaign. In the Abyssinian war three hospital ships were used. Their fitting out was carefully superintended by Deputy Inspector-General Dr Massy, and appears to have answered admirably. A full account of one of these ships ("Queen of the South") was given by the late Staff-Surgeon Charteris, to which reference may be made. The ventilation, as shown by the amount of carbonic acid (0·708 per 1000 volumes) was very good. The superficial space between decks per man was on the night of the experiment 154 feet, and the cubic space no less than 1076. During the Ashanti war (1873–4) the line-of-battle ship "Victor Emanuel" was used as an hospital ship, and was most successful. A very full and detailed account of it is given by the late Brigade-Surgeon T. M. Bleckley, C.B., in medical charge.[1] The floor space per head was generally about 50 square feet, and the cubic space about 480, although it was originally intended to be less. Hospital ships were also used during the Egyptian campaigns of 1882 and following years. For a good description of the hospital ship "Ganges," by Brigade-Surgeon G. C. Gribbon, M.B., Medical Staff, see *Army Medical Reports*, vol. xxvi. p. 327.

However convenient, and indeed necessary, they are, it must be clearly understood that they are not equal to an hospital on shore. It is impossible to ventilate and clean them thoroughly. The space is small between decks. The wood gets impregnated with effluvia, and even sometimes the bilge is contaminated. Dr Becher, late pathologist in China, stated that even in the very best of the hospitals used there, it was quite clear that in every wound there was evidence of a slight gangrenous tendency. In fact, it is perhaps impossible to prevent this except by the freest ventilation and the most vigorous antiseptic treatment.

The principle of separation should be carried out in these ships—one ship for wounded men, another for fevers, a third for mixed cases; or if this cannot be done, separate decks should be assigned for wounded men and fever cases. In fine weather the sick should be treated on deck under awnings. The between-decks must be thoroughly ventilated, and all measures of fumigation, frequent lime-washing, &c., must be constantly employed. Charcoal, also, in substance should be largely used. Warming by stoves must be used in damp and cold weather, and, if so, advantage should be taken of this source of heat, and of all lights, to improve ventilation.

Ships of one deck are better than two; but as they will hold a very small number of sick, two decks are commonly used. But not more than two decks should be used; and if there be a third or orlop deck, it should be kept for stores. Sometimes, if there are two decks, the upper deck is used for officers and the lower for troops, but the reverse arrangement should be adopted.

The ventilation of the between-decks, in addition to Edmond's plan, should be carried on by tubes, which, if the central shaft is acting, will be all inlets, and can be so arranged as to cause good distribution of the air.

The fittings of an hospital ship should be as few and simple as possible, and invariably of iron. Tables should be small, and on thin iron legs. Swinging cots are indispensable for wounded men, and the appliances for the receiving and removing the excreta of dysenteric and febrile patients must be carefully attended to. Berths should not be of wood, but of iron bars, which are much more easily laid bare and cleaned.

The supply of distilled drinking water should be as large as possible, and

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[1] *Army Medical Reports*, vol. xv. p. 260.

a good distilling apparatus should be on board, whether the vessel be a steamer or not.

The laundry arrangements are most important, and it would be a good plan, on a large expedition, to have a small ship converted entirely into a laundry. It would not only wash for the sick, but for the healthy men also. So also a separate ship for a bakery is an important point, so as to have no baking on board the hospital ship.

On board the hospital ship there should be constant fumigation; lime-washing, whenever any part of the hospital can be cleaned for a day or two, and, in fact, every other precaution taken which can be thought of to make the floating hospital equally clean, dry, well aërated and pure as an hospital on shore.

On board hospital ships it is often easy to arrange for sea-bathing and douching; it should never be forgotten what important curative means these are.

In case pyæmia and erysipelas, or hospital gangrene occur, the cases must be treated on deck, no matter how bad the weather may be. Good awnings to protect from wind and rain can be put up.

If cows or goats are kept on board to supply milk, their stalls must be kept thoroughly cleaned. But generally it is better to obtain milk from the shore.

CHAPTER VI.

WAR.

The trade of the soldier is war. For war he is selected, maintained, and taught. As a force at the command of a government, the army is also an agent for maintaining public order; but this is a minor object, and only occasionally called for, when the civil power is incompetent.

In theory, an army should be so trained for war as to be ready to take the field at literally a moment's notice. The various parts composing it should be so organised that, almost as quickly as the telegram flies, they can be brought together at any point, prompt to commence those combined actions by which a body of men are moved, fed, clothed, kept supplied with munitions of war, maintained in health, or cured if sick, and ready to undertake all the engineering, mechanical, and strategical and tactical movements which constitute the art of war.

That an organisation so perfect shall be carried out, it is necessary that all its parts shall be equally efficient; if one fails, the whole machine breaks down. The strength of a chain is the strength of its weakest link, and this may be said with equal truth of an army. Commissariat, transport, medical, and engineering appliances are as essential as the arts of tactics and strategy. It is a narrow and a dangerous view which sees in war merely the movements of the soldier, without recognising the less-seen agencies which insure that the soldier shall be armed, fed, clothed, healthy, and vigorous.

During peace the soldier is trained for war. What is meant by training for war? Not merely that the soldier shall be taught to use his weapons with effect, and to act his part in that machine where something of mechanical accuracy is imprinted on human beings, but that he shall also know how to meet and individually cope with the various conditions of war, which differ so much from those of peace.

It is in the nature of war to reinduce a sort of barbarism. The arts and appliances of peace, which tend, almost without our care, to shelter, and clothe, and feed us, disappear. The man reverts in part to his pristine condition, and often must minister as he best may to his own wants. No doubt the State will aid him in this; but it is impossible to do so as completely as in peace. Often, indeed, an army in war has maintained itself in complete independence of its base of supplies, as in almost every campaign there is more or less of this independence of action.

In peace the soldier, as far as clothing, feeding, shelter, and cleanliness are concerned, is almost reduced to the condition of a passive agent. Everything is done for him, and all the appliances of science are brought into play to save labour and to lessen cost. Is this the proper plan? Looking to the conditions of war, ought not a soldier to be considered in the light of an emigrant, who may suddenly be called upon to quit the appliances of civilised life, and who must depend on himself and his own powers for the means of comfort and even subsistence?

There is a general impression that the English soldier, when placed in unaccustomed circumstances, can do nothing for himself, and is helpless. If so, it is not the fault of the man, but of the system, which reduces

him to such a state. That it is not the fault of the man is shown by the fact that, however helpless the English soldier may appear to be in the first campaign, he subsequently becomes as clever in providing for himself as any man. The Crimean war did not perhaps last long enough to show this, but the Peninsular war proved it. The soldier there learned to cook, to house himself, to shelter himself from the weather when he had no house, to keep himself clean, and to mend and make his clothes. Was it not the power of doing these things, as well as the mere knowledge of movements and arms, which made the Duke of Wellington say that his army could go anywhere and do anything? And the wars at the Cape and in New Zealand have shown that the present race of soldiers, when removed from the appliances of civilised life, have not lost this power of adaptation.

The English soldier is not helpless; he is simply untrained in these things, and so long as he is untrained, however perfect he may be in drill and manœuvre, he is not fit for war. The campaign itself should not be his tutor; it must be in the mimic campaigns of peace, in which the stern realities of war are imitated, that the soldier must be trained. Our present field-days represent the very acme and culminating point of war,—the few bright moments when the long marches and the wearisome guards are rewarded by the wild excitement of battle; but the more common conditions of the campaign ought also to find their parallel. Since the Crimean war much has been done to instruct the soldier in the minor arts of war. The establishment of camps has to some extent familiarised him with tent life; the flying columns which go out from Aldershot show him something of the life of the bivouac, and the training in cooking which Lord Herbert ordered is teaching him how to prepare his food. The Autumn Manœuvres have extended this system, and are now making him familiar with the chief conditions of the life in campaign.

A campaign can never be successful unless the men are healthy. How are men to be trained so as to start in a campaign in a healthy condition, and to be able to bear the manifold trials of war? The answer may be given under three heads—

1. Preparation for war during peace.
2. Entry on war.
3. Actual service in war.

SECTION I.

PREPARATION FOR WAR DURING PEACE.

The various conditions of war, which are different from those of peace, are:—

1. *Exposure to the Weather.*—It is a constant observation that men who have led outdoor lives are far more healthy in war than men whose occupations have kept them in houses. The soldier's life should be, therefore, an outdoor one. This can only be done properly by keeping him in tents during the summer. It would be well, in fact, to tent the whole army from the middle of May to the end of September every year. The expense should be looked on as a necessary part of the military establishments. Wooden huts are too like ordinary barracks. As the soldier has often to sleep out in war, he should be accustomed to this also in peace—warm summer nights being first selected to train him. It will soon be found that he will very soon acquire the power of resistance to cold. This plan will also test the

utility of his clothes.[1] It has been found by experiment that, by careful training, even delicate persons can bear sleeping out at night, even in tolerably cold weather, without injury, provided there be no rain. At the latter end of the summer, it would be well to expose the men even to rainy nights, their clothes being adapted for this by the supply of waterproofs; and in the very useful Autumn Manœuvres this plan might be tried with advantage.

At the same time, it is important to have the men raised off the ground, both when in tent and lying in the open air, in all countries where the ground may be moist, or cools rapidly during the night. A very useful field hammock has been invented by Captain M'Quire; it consists of a strong woollen material, which is suspended on two sticks by means of guide-ropes. It makes a comfortable bed, and keeps the body very warm.

It may be thought that training of this kind is needless, and that it may be left to the campaign to accustom the men to exposure, but this is not the case; a number of men are rendered inefficient at the commencement of a campaign simply by the unaccustomed exposure.

2. *Tent and Camp Life.*[2]—The pitching, striking, and cleansing of tents; the digging trenches round the tents, and providing for general surface drainage; the arrangement of the interior of the tent, &c., should all be carefully taught. So also the camp life of the campaign should be closely imitated, and the rules of conservancy most strictly carried out as a means simply of teaching what will be of such importance in war.[3]

3. *Cooking of Food.*—No doubt, in future wars, all governments will endeavour to supply prepared and cooked food, so as to lessen the cost of transport and the labour of the soldier. But as this cannot always be depended upon, the soldier must be trained to cook his ordinary rations. This should not be done for him; he ought to do it himself merely with the appliances he would have in war, viz., his camp-kettle, canteen, and tin plate.

At the commencement of a campaign many men lose flesh and strength, or suffer from diarrhœa, from the food being badly cooked and indigestible.

In the Peninsular war the men became admirable cooks. At first very large camp-kettles, intended for half a company, were used, and were carried on horses. They did not answer, and the men left them behind. Afterwards smaller camp-kettles were supplied, one for each mess of six or eight. Luscombe mentions that the supply of salt was found to be a very important point; he says he had no idea of the value of this condiment till he saw the way in which the men saved every little particle; without it, in fact, animal and even vegetable food is unsavoury.

In the French army on service 8 or 10 men form a corporal's detachment or *escouade.* They have between them one kettle and cover (*marmite,* weight 1·7 kilog.), one large bowl (*grande gamelle,* weight 1 kilog.), and one large drinking vessel (*grand bidon,* weight 1·5 kilog.). Each man has for his personal use a small bowl (*petite gamelle*) and a small drinking vessel (*petit bidon*). They are all of tinned iron. All these vessels are carried by the men, the larger vessels being taken in turn by the men of the mess.

[1] In reference to what was said of the great importance of a hood to the greatcoat for men who sleep out at night, an old observation of Donald Monro is of interest. He states that in 1760 the greater health enjoyed by the Austrian hussars over the other troops was owing to the half-boots and the large cloaks with hoods carried by these men.—*On the Means of Preserving the Health of the Army* (2nd edit., 1780, p. 7).

[2] Reference may be made for fuller details to some excellent treatises on camps published in Germany and Russia, especially by Dr Roth (*Das Zeltlager auf der Lockstädter Heide in Holstein,* 1866) and by Dr Heyfelder (*Das Lager auf der Krasnœ-Selo,* 1868).

[3] Reference has already been made to the very useful *Soldier's Pocket-Book,* by Sir Garnet (now Lord) Wolseley, which gives full details on all these points.

It may be concluded, with regard to this very important matter of cooking utensils, that a man should have a small but very strong canteen, made of unsoldered tin, and with a good deep lid, with a handle which may serve as a frying-pan or second vessel, as well as a cover. The shape of the canteen should be long and flat, and not deeper than is necessary for cooking, so that it may be easily carried. Then all the other vessels, the camp-kettles, for each mess, and the large water-vessels, should be carried for the men. They should be made of thin steel, which is very light for its strength, very durable, and is not acted on by the food.

The different kinds of camp cooking to be taught are stewing, boiling, and making soup, making tea and coffee, cooking preserved vegetables, making cakes of flour, and oatmeal porridge.

Reference has already been made to the great importance of not keeping men too long without food. By a little arrangement men can always carry food, and the proper organisation of supplies and regimental transport would always enable a commanding officer to have some food for his men. In almost all marches, with large bodies of men, and in many actions, there are long periods of inaction during which men could eat food which has been already cooked. The effect of this upon their strength, endurance, and even courage is remarkable. Some instances have been related by officers in which failures resulted entirely from the exhaustion of the men produced by want of food. Surely it is useless to supply ammunition for guns if the men who are to work them have no supply of energy issued also to them.

4. *Water Supply.*—As impure water is a great cause of sickness in war, the soldier should be taught how to recognise impurity, and how to use the simple methods of purification with charcoal, alum, tea, boiling, &c.

5. *Mending Clothes.*—Every soldier carries a hold-all, but many cannot use it properly. It may be suggested whether, in the workshops which are now being established, it would not be well to let every recruit have a month's practice in repairing clothes, and especially boots; simple plans of repair being selected, if it be possible.

6. *Cleanliness.*—In war a source of disease is the want of cleanliness. Very soon the person and clothes get covered with lice; all the garments, outer as well as under, get impregnated with sweat, and become very filthy. The best generals have always been very careful on this point, and have had frequent washing parades. As washing clothes is really an art, the soldier should be taught to do it, not by machinery, but in the rude fashion he must practice during war. Clothes can be partially cleaned by drying and beating.

The hair should be cut short. In the absence of water for washing, the best plan is the small-tooth comb, to keep the hair free from vermin, and it may be a question whether one should not be supplied to every soldier.

Washing the whole body in cold water, whenever it can be done, is not only bracing and invigorating, but strengthens it against vicissitudes of weather, and against dysentery.[1]

SECTION II.

ENTRY ON WAR.

When actual war commences some further steps become necessary.

All experience shows that men under twenty or twenty-one years of age

[1] Both Donald Monro and Lind notice this.

cannot bear the fatigues of war.[1] If possible, then, all men below twenty-one, or at any rate below twenty, should be held back from the campaign, and formed into depôts, whence they may be draughted for active service on occasion. Of course, every means should be taken during their service at the depôts to strengthen and harden them.

All weakly men should also be held back, and every man thus retained should come under the surgeon's superintendence, not in hospital, but while doing his duty.

The men who are about to enter on the campaign should at once commence a more severe training. If there be time to do it, this should be carried to an extent even greater than will be demanded in war, in the manner of the Romans, who trained their soldiers so severely in peace that war was a relief. Footsoreness is very common at the commencement of a campaign, and often gives great trouble.

Certain changes in the food of the men should be made.

The exertions of war, bodily and mental, are often very great, and demand an increased quantity of food, especially in the nitrogenous and fatty elements; an increased amount of meat and bread, with the addition of fat bacon, cheese, and peas or beans, should be given, so as to bring the daily amount of nitrogen to 375 or 400 grains, and of carbon to 5000 grains daily. During the war every effort should be made to get bread and flour supplied in lieu of biscuit, and to supply red wine. As one of the perils of war is the occurrence of scurvy, the supply of fresh vegetables should be increased; if these at all fail during the campaign, the preserved vegetables must be issued, and the other precautions taken. Considering the benefit apparently derived in Captain Cook's voyages from wort made from malt, it might be worth while to try the effect of introducing this as a beverage; it can be readily made.

Donald Monro mentions that at Bremen, in 1762, when no vegetables could be got, and fresh meat was dear, and scurvy broke out, infusion of horse-radish was found to be useful. Spruce beer was also used.

SECTION III.

ACTUAL WAR.[2]

Experience has showed in hundreds of campaigns that there is a large amount of sickness. The almost universality of this proves that, with every

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[1] The examples are numerous, but the following are often quoted. In 1805 the French army broke up at Boulogne, and marched 400 leagues (French) to fight at Austerlitz; the youngest soldier was twenty-two years old; they left scarcely any sick or wounded *en route*. In 1809 the French marched from the German provinces to Vienna; not half the army were aged twenty years; the hospitals were filled with sick. In 1813 and 1814 the despatches of Napoleon are filled with complaints of the "boys" who were sent him; he said—"I must have grown men: boys serve only to encumber the hospitals and roadsides."

[2] *Sanitary Rules of the Romans during War.*

Vegetius (*De Re Militari*, lib. iii. cap. 2) says the Romans took great care that the men should be well supplied with good water, good provisions, firewood, sufficient quantity of wine, vinegar, and salt. They endeavoured to keep their armies in good health by due attention—

1. To *Situation;* avoiding marshes and dry uncovered ground in summer; in having tents, frequently changing camps in summer and autumn.
2. To the *Water;* for bad water was considered to be very productive of diseases.
3. To the *Seasons;* not exposing men to heat. In winter, taking particular care that the men never were in want of firewood or of clothing.
4. To *Food* and *Medicine;* the officers saw that the men had their regular meals, and were well looked after by the commissariat.

care, the conditions of war are unfavourable to health. The strenuous exertions, the broken rest, the exposure to cold and wet, the scanty, ill-cooked, or unwholesome food, the bad water, and the foul and overcrowded camps and tents, account for the amount of disease.

The amount of illness varies with the nature of the campaign and the genius of the commander.

If the records can be trusted, it would seem that the English have been more unhealthy than the French in their wars, but there is no great trust to be placed in war statistics. In the Peninsula the mean daily number of sick was never below 12 per cent. except for a short time in the lines of Torres Vedras, when it fell to 9 or 10. Sometimes it amounted to 15, 20, or 25 per cent. In the Crimea the immense sickness of the first winter is but too well remembered.

Army Medical Regulations.[1]

Before an army takes the field, the Director-General may appoint a medical officer to act as Field-Inspector under the Principal Medical Officer, but not to act as Sanitary Officer. The Director-General prepares lists of all medicines, stores, &c. The amount of transport and of stores is laid down.

The Director-General also, on requirement by the War Office, gives an account of everything in the proposed scene of operations which may affect the health of the men. He appoints a Sanitary Officer to be attached to the Quartermaster-General's department. He issues instructions to the Principal Medical Officer and Sanitary Officer on all matters connected with rations, clothing, shelter, precautions for preventing disease, &c.

The Sanitary Officer inspects all proposed encamping ground, quarters, &c., and supervises the sanitary arrangements of all camps, towns, hospitals, &c. The Principal Medical Officer advises the Commander of the Forces on all matters affecting health, such as rations, shelter, clothing, &c., and may, with the sanction of the Commander of the Forces, issue instructions on such matters to the medical officers.

The Sanitary Officer inspects the camp daily; accompanies the Quartermaster-General on the march, and gives his advice on all sanitary points. He is supplied with information to aid him in his work from all Principal Medical Officers of general hospitals, divisions, and brigades in the field. He transmits a weekly sanitary report to the Principal Medical Officer.

Causes of Sickness and Mortality in War.

The chief causes of sickness and mortality in the English army have been, in order of fatality—

1. Diseases arising from *improper and insufficient food*, viz., general

5. To *Exercise;* by keeping the troops during the day-time in constant exercise,—in dry weather in the open air; in time of rain or snow under cover; for exercise was believed to do a great deal more for the preservation of health than the art of physic.

The Præfectus-Castrorum (Quartermaster-General), an officer of high rank in the Roman army, looked after the sick, and provided everything required by the surgeons. Both Livy and Tacitus mention that the commanding officers used to visit the sick and wounded soldiers, to inquire if they were well taken care of. The great health of the Roman soldiers was evidently owing to their great temperance; their excellent warm tents made of hides; their carefully kept camps; the warm war dress or sagum, and their constant exercise.

Rules of the Macedonians.—The only notice of the means by which Alexander the Great preserved so wonderfully the health of his small army seems to be a statement that he frequently changed his encamping grounds (*Quintus Curtius*, lib. v. 32). This great soldier must certainly have been acquainted with the art of Hygiene.

[1] *Army Medical Regulations*, 1885, part 6, section viii. paras. 1123–46.

feebleness and increased liability to malarious fevers, dysentery, diarrhœa, &c., and production of scurvy and scorbutic dysentery.

2. *Malarious* disease from unhealthy sites.

3. *Catarrhs*, bronchitis, pleurisy, pneumonia, rheumatism, dysentery (?), produced by inclemencies of weather.

4. *Spotted typhus*, kept up and spread (if not produced) by overcrowding and uncleanliness.

5. *Contagious dysentery*, arising from foul camps and latrines.

6. *Enteric* and perhaps other fevers, produced by foul camps.

7. *Exhaustion and debility*, produced by excessive fatigue—a very great predisposing cause of almost all other diseases.

8. *Cholera*, in India especially, but liable to occur anywhere.

9. *Yellow fever* in the West Indian and West African campaigns.

10. *Plague* in Egypt, now very unlikely, but the possibility of it not to be lost sight of.

11. The *exanthemata* occasionally.

12. *Ophthalmia.*

13. *Venereal* diseases.

Of these diseases the most fatal have been scorbutic dysentery and typhus. It is indeed curious to see how invariably in all wars the scorbutic taint occurs, and frequently in how early a period of the campaign it can be detected. There almost seems to be something in the fatigues and anxieties of war which assists its development. It frequently complicates every other disease, impresses on them a peculiar character, and renders them very intractable to treatment. This is the case with dysentery, enteric fever, malarious fever, and spotted typhus. With the last disease, especially, it has intimate relations, and contributes apparently to its propagation by rendering the frame more easily attacked by the specific poison.

One of the most important preventive measures to be adopted in war is the prophylactic treatment of scurvy. But with a full knowledge of this, the disease cannot always be avoided. The Federal Americans were fully aware of the necessity of combating it, and made immense efforts to do so. They did not succeed, and so marked and so general was the scorbutic taint in their army, that its combinations with enteric fever and malaria have been looked upon as new diseases.

If scurvy could be prevented, every other war disease ought to be comparatively trifling. Inflammations from exposure, exhaustion from fatigue, and gastro-intestinal affections from improper food and atmospheric vicissitudes, would still occur; but the ravages of typhus, enteric fever, malaria, and dysentery ought to be trifling, and easily prevented.

To prevent scurvy, then, is one of the most important measures.

If scurvy be absent, typhus fever is readily treated; isolation and the freest ventilation are certain to stop it. The only great danger would be in a besieged and crowded fortress. In such a place it may be beyond control, but early recognition and prompt isolation, as far as it can be done, and as free ventilation as possible, may perhaps stop it. It is in such cases that we should freely use the nitrous acid fumes and other disinfectant vapours.

Enteric (typhoid) fever and contagious dysentery, in the same way, ought with certainty to be prevented in a camp. Recent experience, however, in Affghanistan, South Africa, and Egypt has shown what ravages enteric fever can make, and how rapidly it is generated and spread among troops in campaign, especially when the men are mostly young. This is certainly due to the neglect of proper hygienic measures. The first case even should make us take urgent measures for the cleansing of latrines, or, better still, the

closing of all the old and the opening of fresh ones. But the best plan of all is to shift the encamping ground, and we should remember the old Roman maxim, based doubtless on observation of enteric fevers, that this must be done more often in the autumn.

The exanthemata, measles, and scarlet fever sometimes spread largely through an army; the only plan is to separate all cases, and send them one day's march on the flank of the army, if it can be done, not in the direction of the line of supplies.

Plague probably demands the same measures as typhus.

The measures for cholera have been already sufficiently noted.

The diseases of exposure can hardly be avoided, but may be lessened by warm clothes and waterproof outer coverings. Flannel should be used next the skin all over the trunk and extremities, and is indispensable. One of the most important means to enable troops to stand inclemencies of weather, and indeed all fatigues, is hot food. Coffee and tea are the best; and hot spirits and water, though useful as an occasional measure, are much inferior, if indeed they do any good at all apart from the warmth. But the supply of *hot* food in war should be carefully attended to, especially in the case of breakfast, after which men will undergo without harm great exposure and fatigue.

It is unnecessary to enter at greater length into the measures to prevent the diseases of war, for the proper plans have been all enumerated previously. We may conclude only that much can be done to prevent disease, but we must also remember that the course of campaigns sometimes is too violent and overpowering for our efforts, and that wars, like revolutions, will never be made with rose water.

Recapitulation of the Duties of a Sanitary Officer during War.

To go forward with the officers of the Quartermaster-General's department, to choose the camping ground; arrange for surface drainage; if necessarily in a malarious place, make use of all obstacles, as hills, trees, &c., to throw off the malaria from the tents; place the tents with the openings from the malarious quarter. If possible, never take low hills (100 to 250 feet) above marshy plains. Arrange for the water supply, and for the service of the men, animals, and washing. As soon as possible fix the sites for the latrines; have them dug out, and make dry paths to them. As soon as the tents are pitched, visit the whole camp, and see that the external ventilation is not blocked in any way, and that the tents are as far off each other as can be permitted. Assign their work to the scavengers, and mark out the places of deposit for refuse. It is of the greatest importance that all refuse should be immediately and completely destroyed by fire. The destruction of the stools of enteric, dysenteric, and choleraic patients by the same means would probably prove a most important precaution. The daily inspection should include all these points, as well as the inspection of the food and cooking, and of the slaughter-houses. If the camp be a large one, a certain portion should be selected every day for the careful inspection of the individual tents, but it should be made in no certain order, that the men may not prepare specially for the inspection.

A set of rules should be drawn up for the men, pointing out the necessity of ventilation, cleanliness of their persons, tents, and ground around them, and ordering the measures which are to be adopted. This will have to be promulgated by the general in command.

In the daily work, a certain order and routine should be followed, so that nothing shall be overlooked.

The Sanitary Officer of a large camp can never perform his duties without the most unremitting support from the medical officers attached to regiments, who are the sanitary officers of their respective corps. Not only must they inspect their own regimental camps, but by an immediate report to the Sanitary Officer of any disease which can possibly be traced to some camp impurity, they should render it possible for the commencing evil, of whatever kind, to be detected and checked.

As early as possible every morning the number of men reported sick from each regiment should be made known, and a calculation made of sick to strength, and then, if any regiment showed any excess of sick, the sanitary state of its camp should be specially and thoroughly investigated.

Hospitals in War.[1]

With an army in the field, hospitals are of several kinds.

1. The principal General Hospital at the base of operations.
2. The Intermediate Hospitals, divided into—
   a. The Field Hospitals stationed at the base or on the line of communication.
   b. The Field Hospitals proper, which move with the corps, and include the *dressing stations* and *regimental stations.*

The old *Regimental Hospital* is now definitely abolished, but medical and surgical assistance is provided by a medical officer with one or two attendants, accompanied by bearers, with stretchers when required, as in action in the field. The sick are treated in the field hospitals first, and then passed on to the intermediate hospitals in rear, which are again evacuated, as occasion requires, by transfer of patients to the principal general hospital at the base. This last will be in a convenient station on the frontier, or, in case of an insular nation like ourselves, on some sea-coast easily accessible. It is from it that men will ultimately be invalided home if unfit for further service.

For each army corps (of nominally 36,000 men) 25 field hospitals are appointed—12 to move with the corps, and 13 to be stationed at the base and along the lines of communication;[2] each is equipped for 200 sick, and may be divided into half hospitals for 100 each, if necessary. Slight cases would be treated in the field hospitals, but all cases likely to take any time should be sent to the rear of operations as soon as possible. Cases of fever (typhus and enteric) ought to be removed as soon as possible far from the field force. It is of great importance that they should not be put near surgical cases, which ought to be kept separate, or mixed only with non-communicable diseases. This (the separation of fever from surgical cases) was a Peninsular rule of Sir James M'Grigor, and should never be forgotten. Ophthalmic cases ought also to be isolated.

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[1] Sir James M'Grigor, in the Peninsula, established divisional hospitals in front, and convalescent hospitals in the rear, where the men were received *en route* to the depôt. Although he does not describe his system fully in his paper in the *Medico-Chirurgical Transactions,* (vol. vi.), it is evident from his autobiography that his constant practice was to send off the sick as soon as possible. This is shown by his narrative of the retreat from Burgos, when he saved Lord Wellington from the mortification of abandoning his sick and wounded to the enemy. Professor Sir T. Longmore, in his most instructive work on transport, has detailed at length the means of transport of the sick and wounded, and other important matters of the kind.

[2] For full details of the new hospital organisation in the field, see Professor Sir T. Longmore's work, *Gunshot Injuries* (1877), sect. ix. chap. 1; also *Army Medical Regulations* (1885), part 2, sect. ix.

The hospitals in rear may be at some distance, but connected either with a railway or by water carriage. It is of great importance to keep continually sending patients from the division and general hospitals with the army to the hospitals in rear. It is not only to keep the hospitals in front empty for emergencies, and to facilitate all movements of the army, but it has a great effect on the army itself. A great hospital full of sick is a disheartening spectacle, and often damps the spirits of the bravest men. The whole army is higher in hope and spirits when the sick are removed, as was shown remarkably by the Austrian experience of 1859. The sick themselves are greatly benefited by the removal; the change of scene, of air, of ideas, has itself a marvellous effect, and this is another great reason for constantly evacuating the sick from the hospitals in front.

The men who are reported for hospital in war must be divided into several classes—

1. Slightly wounded should be treated in the field or intermediate hospitals, and then return to duty.

2. Severely wounded at first in the field hospitals, then sent to the intermediate hospital, and then to the rear, as convalescence is always long.

3. Slight colds, diarrhœa, &c., treated in the field hospitals.

4. Severer colds, bronchitis, pleurisy, pneumonia, dysentery, &c., should be sent at once to the intermediate hospital, and then to the rear as soon as they can move with safety.

5. Typhus fever at once to the hospitals in rear, if possible without entering the field hospitals.

6. Enteric cases, also, should be sent to the rear, and, in fact, all severe cases. The field hospitals should be always almost empty, and ready for emergencies.

These hospitals in rear may be even two or three days' journey off, if conveyance be by water, or one or two days if by rail. Sick and wounded men bear movement wonderfully well, with proper appliances, and are often indeed benefited.[1]

The proper position for the hospitals, at the base of operations, must be fixed by the commander of the forces at the commencement of the campaign, as he alone will know what point will be the base of supplies, and it is of importance to have these great hospitals near the large stores which are collected for the campaign.

It seems now quite clear that these hospitals should not be the ordinary buildings of the country adapted as hospitals. Such a measure seldom succeeds, and the mere adaptation is expensive, though probably always imperfect.[2] Churches should never be taken, as they are not only cold, but often damp, and there are often exhalations from vaults.

The French, Austrian, and American experience is in favour of having the hospitals in rear made of tents or wooden huts. The huts are perhaps the best, especially if the winter be cold. They were very largely used by the Federal Americans, who gave up entirely converting old buildings into hospitals. The best huts which were used in the Russian war of 1854–56 were those erected at Renkioi from Mr Brunel's design; each held fifty men

[1] On this and other points of the like kind, see Report on Hygiene in the *Army Medical Report* for 1862, pp. 349, 350.

[2] Donald Monro says that, in 1769, the houses in Germany taken for the sick were improved by taking away the stoves and putting in open fire-places. In the Peninsula the Duke of Wellington appeared to have a dread of fever attacking the army. Luscombe tells us that the Duke asked the principal medical officer every day as to the appearance of fever. He also improved the hospitals by ordering open fire-places.—*Luscombe*, p. 6.

in four rows. This plan, however, is not so good a one as having only two rows of beds. Hammond[1] states that in the American war the best size has been found to be a ward for fifty men with two rows of beds; length of ward, 175 feet; width, 25; height, 14 feet; superficial area per man, 87 feet; cubic space per man, 1200 feet. Ventilation was by the ridge, an opening 10 inches wide running the whole length, and by openings below, which could be more or less closed by sliding doors. Some of the American hospitals held from 2000 to 2800 beds.[2] It is probable, however, that smaller wards (for 25 men) would be better. The huts used at Suakim are described in the *Army Medical Department Reports*, vol. xxvi. They were of wood, the upper half of the walls moveable, or provided with bamboo chicks or matting. Roof of cork, covered with Willesden waterproof paper, and ventilated by means of metal cowls. Number of beds, 12; with 850 cubic feet each.

An hospital constructed of such huts can be of any size, but there must be several kitchens and laundries if it be very large. If space permit, however, it seems desirable to have rather a collection of smaller hospitals of 500 beds each, separated by half a mile of distance, than one large hospital.

The arrangement of the huts must be made according to the principles already laid down. Dr Hammond writes thus of these hospitals:—

"It will, perhaps, not be out of place again to insist on the great advantages of these temporary field hospitals over those located in permanent buildings in towns. Nothing is better for the sick and wounded, winter and summer, than a tent or a ridge-ventilated hut. The experience gained during the present war establishes this point beyond the possibility of a doubt. Cases of erysipelas or of hospital gangrene occurring in the old buildings, which were at one time unavoidably used as hospitals, but which are now almost displaced for the ridge-ventilated pavilions, immediately commenced to get well as soon as removed to the tents. But in one instance that has come to my knowledge has hospital gangrene originated in a wooden pavilion hospital, and in no instance, as far as I am aware, in a tent. Hospital gangrene has been exceedingly rare in all our hospitals, but two or three hundred cases occurring among the many wounded, amounting to over 100,000 of the loyal and rebel troops, which have been treated in them. Again, wounds heal more rapidly in them, for the reason that the full benefit of the fresh air and the light are obtained. Even in fractures the beneficial effects are to be remarked."[3]

Baron Larrey, in his useful work,[4] describes the plans adopted by the French in the Italian war of 1859. At Constantinople, during the Crimean war, the French were apparently very well installed; the best buildings in Constantinople were assigned to them, and they were arranged with all the accuracy of organisation which distinguishes the French. The results were not, however, favourable, especially in the spring of 1856, when typhus spread through many of the hospitals and caused great mortality.[5] Taught

[1] *On Hygiene*, p. 355.

[2] See Report on Hygiene, in the *Army Medical Report* for 1862, p. 345 *et seq.*, for a fuller description.

[3] *On Hygiene*, p. 397.

[4] *Notice sur l'Hygiène des Hopitaux Militaires*, 1862.

[5] Larrey mentions some striking instances of the effects of overcrowding. At Rami-Tchifflick the hospital was fixed for 900 by the surgeon in charge, who allowed no more; it remained healthy. His successor increased the beds to 1200 and then to 1400. Typhus became most severe, and spared no one (*ni infirmiers, ni sœurs, ni médecins*). In the hospital at Pera there was the same mistake and the same results. Typhus caused 50 per cent. of the deaths. At the hospital of the École Militaire no crowding was permitted, and

by this experience, in the Italian war of 1859 the French distributed their sick in small hospitals whenever they could find a building, and in this way the extension of the specific diseases was entirely stopped.

In the Franco-Prussian war of 1870–71 the Germans made great use of temporary hospitals, and distributed their sick and wounded over almost the whole of Germany. The plans were very similar to those used in the Crimean and American wars. In some of the large cities, as at Berlin, immense hospitals, with railways and every appliance, were fitted up. The experience as regards hospital gangrene and erysipelas was favourable, but there were many cases of pyæmia in some of these hospitals.

To sum up, the hygiene of field hospitals in war (the rules are derived from our own Crimean experience, and that of the wars which have taken place since) is as follows:—The field, including the intermediate, hospitals to be made of tents; the tents being well constructed, of good size, thoroughly ventilated, the flaps being able to be raised so as almost, if desired, to make the tent into an awning. The most convenient and best are the hospital marquees of the new pattern, except for their considerable weight. The new double circular tents will now be used: they are a great improvement on the old bell-tent, and lighter than the marquee. Each weighs 100 ℔ dry, and four patients are put in a tent. For operating purposes, the central pole can be removed and a tripod support substituted, so as to leave the centre free.

The ground round the tents to be thoroughly drained, kept very clean, and replaced from time to time. The tent floor to be covered with clean, and, if possible, *dried* earth, or charcoal, and to be then covered with a waterproof cloth, or boarded, if the camp be one of position. In either case the greatest care must be taken that the ground does not get soaked and filthy. Every now and then (if possible every ten days or so) the tents should be shifted a little.

If it can be done, the sick should be raised off the ground. Iron bedsteads are cumbrous, but small iron pegs stuck in the ground might carry a sort of cot or hammock. The advantage of a plan of this kind is, that by means of holes in the sacking, wounded men can have the close-stool without much movement. For fever cases it permits a free movement of air under the patient.

The stationary general hospitals in rear should be of tents or wooden huts, but never of converted buildings, or of hospitals used by other nations. Here, of course, iron bedsteads, and all the appurtenances of a regular hospital, are brought into play.

Whenever practicable, the rear hospital should have water-closets and sewers. At Renkioi, in Turkey, Mr Brunel supplied square wooden sewers about fifteen inches to the side; they were tarred inside, and acted most admirably, without leakage, for fifteen months, till the end of the war. The water-closets (Jennings' simple siphon), arranged with a small water-box below the cistern to economise water, never got out of order, and, in fact, the drainage of the hospital was literally perfect. Dr Parkes had little doubt such well-tarred wooden sewers would last two or three years.

There is one danger about wooden hospitals, viz., that of fire. The huts should, therefore, on this ground alone, be widely separated; each hut should have, about ten feet from it, an iron box for refuse. Wooden boxes do not answer, as in the winter live cinders get thrown in, and there is

typhus caused only 10 per cent. of the deaths. In the French ambulances in the Crimea the same facts were noticed. Double and treble numbers were crowded into some, and they were ravaged by typhus; others were not allowed to be crowded, and had little typhus.

danger of fire. These boxes should be emptied every morning by the scavengers, and the contents burned as soon as possible. Water must be laid on into every ward.

The arrangement of the buildings is a simple matter, but must partly be determined by the ground. Long open lines are the best. An hospital of this kind, completely prepared in England, can be put up at a very rapid rate,[1] supposing there be no great amount of earth-work, and that the supply of water and of outlet for sewage be convenient. So that, if commenced at once at the beginning of a campaign, accommodation would soon be provided.

Circumstances may of course render it necessary to take existing buildings for hospital purposes, but it ought always to be remembered that it is running a very great risk, and nothing but rigid necessity ought to sanction it.

Laundry Establishment.

This part of an hospital must be organised as early and as perfectly as possible. The different parts must be sent out from England, viz., boiler, drying-closet, washing-machines, and wringing-machines. The washing in war can never be properly done by the people among whom the war is carried on. Every appliance to save labour must be used, and after calculating what amount of laundry work has to be done for a presumed number of sick, just twice the amount of apparatus should be sent out, partly to insure against breakage, partly to meet moments of great pressure. The drying-closet, especially, is a most important part of the laundry, as its heat can be used to disinfect.

Amount of Hospital Accommodation.

This must not be less than for 25 per cent. of the force, with reserve tents in rear in case of need.

Cemeteries in war must be as far removed as possible; the graves dug deep, and peat charcoal thrown in if it can be procured. Lime is generally used instead, but is not quite so good. If charcoal cannot be got, lime must be used. If the army is warring on the sea-coast, burial in the sea might be employed. But cremation would be best, and forms of ambulatory furnaces have been proposed.

Sanitary Duties connected with a War Hospital.

In addition to the usual sanitary duties of an hospital, there are one or two points which require particular attention in the field.

The first of these is the possible conveyance of disease by the exceedingly dirty clothes, which may perhaps have been worn for weeks even without removal, in the hard times of war. Typhus, especially, can be carried in this way.

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[1] The hospital at Renkioi, in Turkey, in the Crimean war, was made of such large huts (50 men in each) that its rapidity of erection is no guide to others; yet it was marvellously soon put up. The first beam was laid on the 24th May 1855; on the 12th July it was reported ready for 300 sick, every ward having water laid on, baths and closets, and an iron kitchen and laundry being also ready; on the 11th August it was ready for 500, and on the 4th December for 1000 sick. In January 1856 it was ready for 1500 sick, and in a short time more 2200 could have been received. The number of English artisans was only forty, but we had native workmen, and if we had had eighty English artisans it would have been ready for 1000 sick in three months. Smaller huts could be put up in much less time if the ground requires no terracing.

To provide for this, every hospital should have a tent or building for the reception of the clothes; here they should be sorted, freely exposed to air, and the dirty flannels or other filthy clothes picked out. Some of these are so bad that they should at once be burnt, and the Principal Medical Officer, at the beginning of a campaign, should have authority given him to do this, and to replace the articles from the public store.

The articles which are not so bad should be cleansed. The cleansing is best done in the following way:—If the hospital have a laundry and drying-closet, they should be put first in the drying-closet for an hour, and the heat carried to 220° Fahr. Then they should be transferred into the fumigation box; this is simply a tin-lined box or large chest. The clothes are put in this, and sulphur placed above them is set on fire, care being taken not to burn the clothes; or nitrous acid fumes should be used. After an hour's detention in the fumigating box, they should be removed to the soaking tubs. These are large tubs with pure water, put in a shed or tent outside the laundry. A little chloride of lime can be added to the water. They should soak here for twenty-four hours, and then go into the laundry and be washed as usual. This plan, and especially the heating and fumigation, will also kill lice, which often swarm in such numbers.

Another point of importance is to bathe the men as soon as possible. The baths of a war hospital at the base of operations should be on a large scale, and the means for getting hot water equally large. The men's heads, if lousy, should be washed with a little weak carbolic acid, which kills the lice at once. The smell is not agreeable, but that is not of real consequence.

In a war hospital, also, the use of charcoal in the wards, antiseptic dressings, the employment of disinfectants of all kinds, is more necessary than in a common hospital.

As a matter of diet, there should be a large use in the diet of antiscorbutic food, vegetables, &c., and antiscorbutic drinks should be in every ward, to be taken *ad libitum*—citric acid and sugar, cream of tartar, &c. The bread must be very good, and of the finest flour, for the dysenteric cases.

Sieges.

The sanitary duties during sieges are often difficult. Water is often scarce, disposal of sewage not easy, and the usual modes of disposal of the dead cannot, perhaps, be made use of. If sewage is not washed away, and if there is no convenient plan of removing it by hand, it must be burnt. Mixing it with gunpowder may be adopted if there is no straw or other combustible material to put with it.

If food threaten to run short, the medical officer should remember how easily Dr Morgan's process of salting meat can be applied, and in this way cattle or horses which are killed for want of forage, or are shot in action, can be preserved. For sieges, as vegetables are sure to fall short, a very ample supply of lemon-juice and of citric acid, citrates, and cream of tartar should be laid in, and distributed largely.

One other point should be brought to the notice of the general in command. In times of pressure, every man who can be discharged from the hospital is sent to the front. This cannot always be avoided. But when there is less pressure, the men should go from the rear hospitals to a depôt, and while there should still be considered under medical treatment, so that they may not too soon be subjected to the hardships of war. They should, in fact, be

subjected again to a sort of training, as if they were just entering on the war. If this is not done, a number of sickly or half-cured men get into the ranks, who may break down in a moment of emergency, and cause great difficulty to the general in command. Some officers think that a man should either be in hospital or at his full duty ; this seems a misapprehension both of the facts and of the best way of meeting them. To transfer a man just cured, from the comforts of an hospital at once to the front, is to run great danger. A depôt, which should be a sort of convalescent hospital, though not under that term, is the proper place to thoroughly strengthen the man just re-covered for the arduous work before him.

BOOK III.

CHEMICAL AND MICROSCOPICAL ANALYSES.

CHAPTER I.

EXAMINATION OF WATER FOR HYGIENIC PURPOSES.

The analysis of water for hygienic purposes has for its object to ascertain whether the water contains any substances either suspended or dissolved which are likely to be hurtful. There are some substances which we know are not likely to do any harm, such as carbonate of sodium, calcium, and magnesium in small quantities. Others are at once viewed with suspicion as indicating an animal origin, and therefore being probably derived from habitations or resorts of men or animals, or from decaying bodies. In other cases substances in themselves harmless, such as nitrates, nitrites, and ammonia, are suspicious from implying the coexistence of, or the previous contamination of the water by, nitrogenous substances. The difficulties in the hygienic examination of water are not inconsiderable. A judgment must be generally come to from a collation of all the evidence, rather than from the results of one or two tests.

Collection.

Great care must be taken that a fair sample of the water is collected in perfectly clean glass vessels (not in earthenware jars)—Winchester quarts, which hold about half a gallon, and can be obtained of most chemists, are most convenient; they should be repeatedly washed out with some of the water to be examined. In taking water from a stream or lake, the bottle ought to be plunged below the surface before it is filled. In drawing from a pipe a portion ought to be allowed to run away first, to get rid of any impurity in the pipe. In judging of a town supply, samples should be obtained direct from the mains, as well as from the houses. The bottle should be stoppered; a cork should be avoided, except in great emergency, but if used it should be quite new, well tied down, and sealed.[1] No luting of any kind (such as linseed meal and the like) should be used.

For a complete sanitary investigation half a gallon is necessary, but with a litre or a couple of pints a pretty good examination can be made if more cannot be obtained. If a detailed mineral analysis is required (which will

[1] *W. O. Circulars*, clause 82, June 1876; clause 12, Jan. 1877; and clause 81, April 1878, direct water to be sent in stoppered glass bottles. See also *Medical Regulations*, 1885, para. 1107, and Appendix 8.

only be seldom) a gallon ought to be provided. It is always advisable to have a good supply in case of breakage or accident. The *W. O. Circulars* direct two Winchester quarts of each sample to be sent.[1] The examination ought to be undertaken immediately after collection, if possible. If this cannot be done, then as short a time as may be should be allowed to elapse, for changes in the most important constituents take place with great rapidity.[2] Pending examination, it ought to be kept in a dark cool place.

The fullest information ought always to be furnished with the sample, the following being the most important particulars:—

1. Source of the water, viz., from tanks or cisterns, main or house pipe, spring, river, stream, lake, or well.
2. Position of source, strata so far as they are known.
3. If a well; depth, diameter, strata through which sunk, whether imperviously steined in the upper part, and how far down. Total depth of well and depth of water to be both given. If the well be open, furnished with cover, or with a pump attached.
4. Possibility of impurities reaching the water: distance of well from cesspools, drains, middens, manure heaps, stables, &c.; if drains or sewers discharge into streams or lakes; proximity of cultivated land.
5. If a surface-water or rain-water, nature of collecting surface and conditions of storage.
6. Meteorological conditions, with reference to recent drought or excessive rainfall.
7. A statement of the existence of any disease supposed to be connected with the water supply, or any other special reason for requiring analysis.

Any further information that can be obtained will always be useful. Each bottle should also be distinctly labelled, so as to correspond with the official letter or invoice.

When it is possible, it is most desirable that the medical officer or analyst should visit the locality itself whence the water is obtained; in this way he may obtain information which might otherwise escape him. If the analysis can be made immediately on the spot, it will be all the more valuable.

SECTION I.

Physical Examination of Water.

The following points are to be noted:—

1. Colour.	4. Lustre.
2. Clearness.	5. Taste.
3. Sediment.	6. Smell.

1. *Colour.*—This may be judged of by allowing any sediment to settle, and then pouring off the supernatant water into a tall glass placed upon a piece of white paper. Or a horizontal tube of colourless glass with glass ends may be used. The stratum should be of sufficient thickness, if possible *two* or *three* feet, but a fair idea of the colour may be obtained with 18 inches or even a foot. The Society of Public Analysts recom-

[1] Frankland recommends from one Winchester quart of the worst waters to three of the purest.

[2] For some interesting experiments on this point, see Hehner, in the *Analyst*, vol. iii. p. 177.

mends 24 inches. If a tube be used, it may either be half full, and the tint compared with the colour of the air in the upper half when directed against a well illuminated white surface; or, better still, it may be filled, and the comparison made with a second tube placed alongside, filled with pure distilled water. Perfectly pure water has a bluish tint, but most ordinary waters have either a greyish, greenish, yellow or brown appearance. The best samples are those coloured bluish or greyish. Green waters owe their colour to vegetable matter, chiefly unicellular *algæ*, and are usually harmless. Yellow or brown waters are most to be feared, as their colour is often due to animal organic matter, chiefly sewage. It is sometimes, however, owing to vegetable matter, such as peat, and under those circumstances it is not generally hurtful. It may also be caused by salts of iron, although in most cases the iron is precipitated as ferric oxide in the sediment.

2. *Clearness.*—The presence or absence of turbidity may be judged of in the same way as the colour, only the water should be shaken up, so as to distribute the suspended matter and simulate its condition when drawn. The depth necessary to obscure printed matter may be used as a measure. Occasionally water remains hazy or turbid even after standing for some time; in such a case the suspended matter is in very fine division, such as is sometimes found with sulphate of calcium, minute scales of mica, &c.

3. *Sediment.*—The nature of the sediment may be roughly judged of by the eye, as to whether it is mineral or vegetable, or stained with iron or the like. The larger living forms, such as *Anguillulæ*, water-fleas, leeches, &c., may also be detected. But the only satisfactory examination is to be made with the microscope.

4. *Lustre.*—The lustre or brilliancy (*éclat*) has been recommended as a good physical indication of the amount of aëration (Gérardin). The different degrees may be noted in any convenient way, such as *nil*, *dull*, *vitreous*, *adamantine*, which is an ascending scale from zero to the maximum brightness.

5. *Taste.*—Taste is an uncertain indication. Any badly tasting water should be rejected or purified before use. Suspended animal organic matters often give a peculiar taste, so also vegetable matters in stagnant waters. Some growing plants, as *lemnia* and *pistia*, give a bitter taste; but most growing plants have no taste. Dissolved animal matter is frequently quite tasteless. As regards dissolved mineral matters, taste is of little use, and differs much in different persons. On an average [1]—

Sodium chloride	is tasted	when it reaches	75	grains per gallon.	
Potassium	,,	,,	,,	20	,, ,,
Magnesium	,,	,,	,,	50 to 55	,, ,,
Calcium sulphate,		,,	,,	25 to 30	,, ,,
,, carbonate,		,,	,,	10 to 12	,, ,,
,, nitrate,		,,	,,	15 to 20	,, ,,
Sodium carbonate,		,,	,,	60 to 65	,, ,,
Iron,	,,	,,	,,	0·2	,, ,,

Iron is thus the only substance which can be tasted in very small quantities. A permanently hard water has sometimes a peculiar *fade*, or slightly saline taste, if the total salts amount to 35 or 40 grains per gallon and the calcium sulphate amounts to 6 or 8 grains. The taste of good

[1] Dr F. de Chaumont, *Army Medical Report for* 1862, vol. iv. p. 355.

drinking water is due entirely to the gases dissolved; water nearly free from carbonic acid hardness, such as distilled water, is not so pleasant as the brisk well-carbonated waters; it may be called flat, but it is difficult to define the kind of taste or absence of it.[1]

6. *Smell.*—The water may be warmed, or distilled, when the odour of fæcal matter is often brought out clearly both in the distillate and residue. If the water is put in a stoppered bottle, which it half fills, and is exposed to light, and then opened and smelt after a few days, commencing putrefaction, or the formation of butyric acid, or something similar, can sometimes be detected. · Tiemann recommends that the water should be heated to 110° or 120° Fahr. (42° to 49° C.); if hydrogen sulphide be present, add a little copper sulphate, which precipitates it, and permits any putrid smell to be perceived.

The Society of Public Analysts[2] recommends heating the water in a wide-mouthed stoppered bottle to 100° F. (38° C.). This may be done by immersing it in warm water. Any particular smell should be recorded, if distinctly recognised,—with its degree of intensity, such as *nil*, *very slight*, *slight*, *marked*, &c., as the case may be. Sometimes an offensive smell is detected on *boiling*, which is not otherwise perceived.[3]

Although the *physical characters* give only an imperfect idea of the value of a water, they are yet important when no further examination can be made. If a water be colourless, clear, free from suspended matter, of a brilliant (or adamantine) lustre, devoid of smell or taste, except such as is recognised to be the characteristic of good potable water, we shall in the large majority of cases be justified in pronouncing it a good and wholesome water; whilst, according as it deviates from these characters, we shall be proportionately justified in regarding it with suspicion. Suspended matter is probably the most dangerous, but it may well be that minute particles, the "resting spores" of disease-causing organisms, may exist without revealing themselves by any visible turbidity (or even to a cursory microscopic examination); these can only be detected by biological tests; nor must we shut our eyes to the possibility of hurtful dissolved substances, so that, when our opinion of a water is based only on its physical characters, the fact ought to be duly recorded.

SECTION II.

Examination of Suspended Matters.

The suspended matters may be either mineral (sand, clay, chalk, fine films of mica, iron peroxide), or dead animal or vegetable matters, or living creatures (plants and animals).

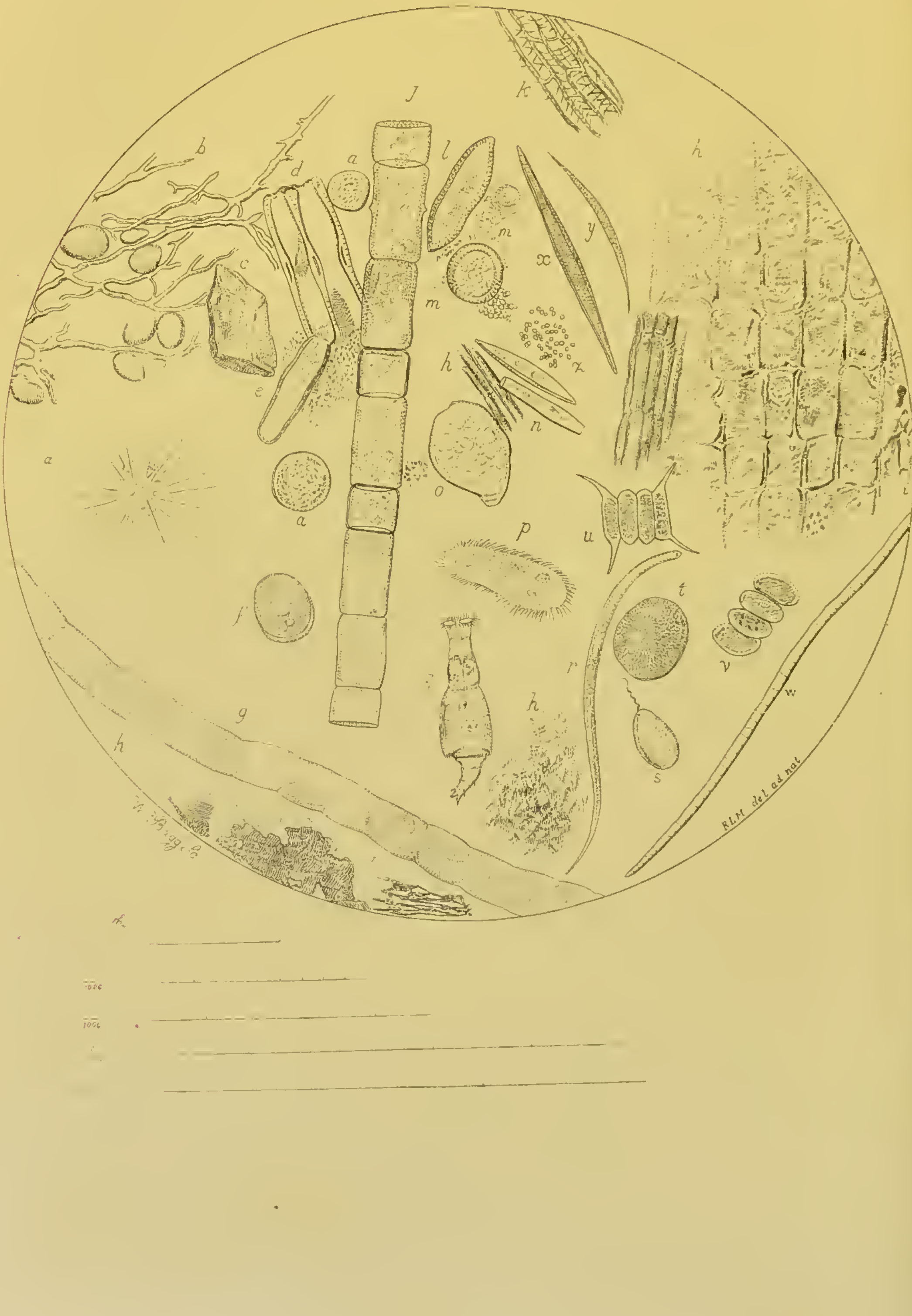
To determine the Nature of the Suspended Matters.

Pour some of the water into a long glass as already described, and observe its appearance. Suspended sand or clay give a yellow or yellow-white turbidity; vegetable humus and peat give a darkish, sewage gives a light brown colour; but the colour or turbidity alone is a very insufficient test.

[1] Arguing from the apparent preference many persons have for water containing some saline matter, Wanklyn has suggested the addition of sodium chloride to drinking water, to the extent of 50 grains per gallon.

[2] *N.B.* Where the letters S.P.A. occur, they mean "Society of Public Analysts," and refer to rules published in the *Analyst*, July and August 1881.

[3] See Dupré, *Analyst*, 1878, p. 265.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Description of Plate I.

Sediment from South Wing Well, Netley, drawn with the Camera lucida *at the distance of* 10 *inches from the centre of eye-piece to paper.*

The presence of infusoria and animals of low type indicates the presence of organic matter, animal or vegetable, and it is therefore important to note their presence; but it has not at present been shown that they are in themselves at all hurtful.

aaa Actinophrys Sol, early and complete stages, × 260.
b Supposed decomposing amœba-like expansions of Gromia fluviatilis, × 435.
c Fragment of carbonate of lime, × 435.
d Navicula viridis, × 435.
e Grammatophora marina? × 435.
f Supposed encysted stage of Euglena viridis, × 435.
g Pinnate conferva, × 780.
hhh Fragments of decaying vegetable matter, × 65.
ii Fragments of carbonaceous substance.
j Part of conferva filament, Conferva floccosa? showing the various conditions of the protoplasm in the old and new cells, × 435.
k Part of leaf of Sphagnum or bog-moss, × 108.
l Grammatophora marina, × 435.
m Minute spores with zoospores? × 435.
n Diatoma hyalinum, × 435.
o Cell with dividing protoplasm, × 435.
p Oxytricha lingua, × 260.
q Rotifer vulgaris, small, × 108.
r Anguillula fluviatilis × 108.
s Peranema globosa, × 108.
t Statoblast of a fresh-water zoophyte? × 108.
u Arthrodesmus incus, × 435.
v Minute Desmidiæ, Scenedesmus obtusus, × 780.
w Oscillaria (oscillatoria) lævis, × 780.
x Homœocladia filiformis? × 435.
y Ankistrodesmus falcatus, × 435.
z Minute moving particles, × 435.—(?) Zoospores.

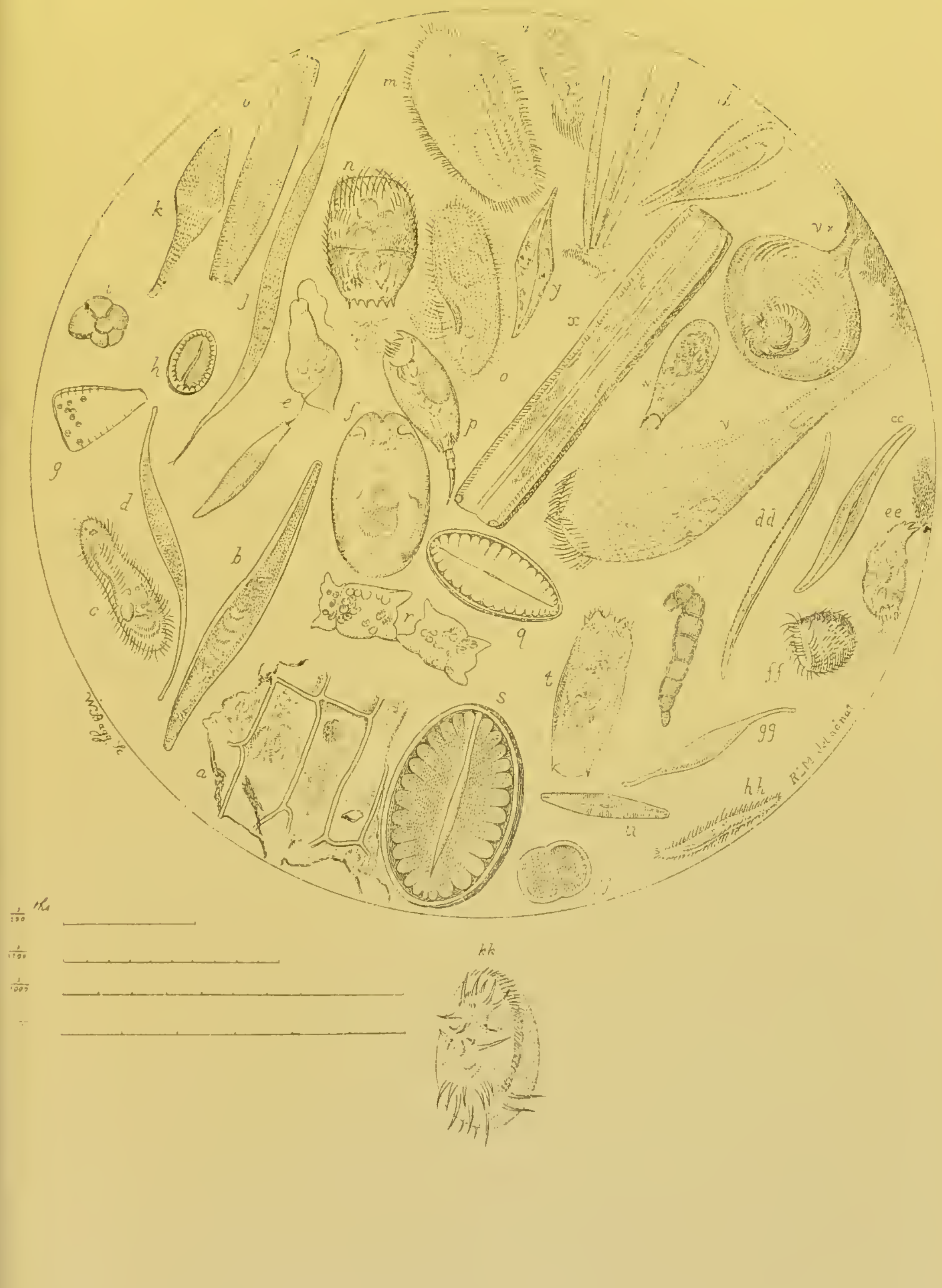
(*To Binder—To face Plate I.*)

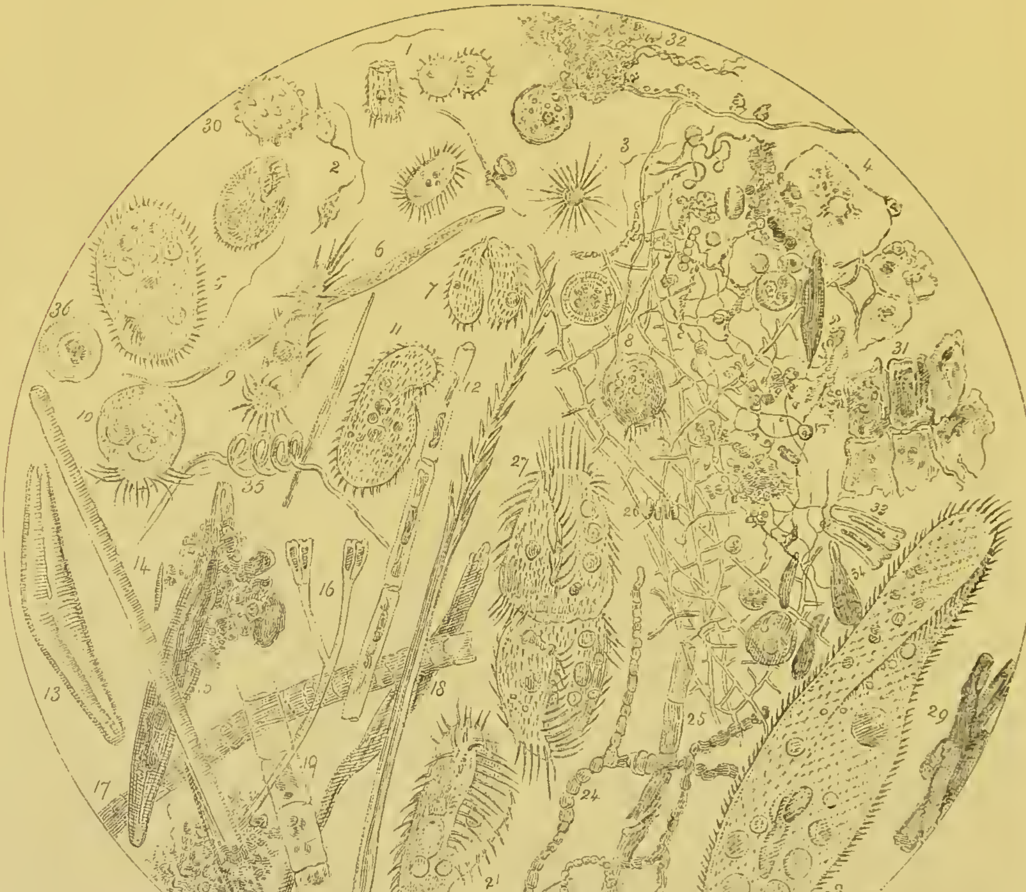
Description of Plate II.

Sediment of Ditch Water, drawn with the Camera lucida *at the distance of* 10 *inches from eye-piece to paper.*

a Decaying vegetable matter, cellular tissue, × 108.
b Pleurosigma formosum, before dividing, × 170.
c Oxytricha gibba, × 108.
d Amphileptus anser, × 170.
e Euglena viridis, × 285.
f Supposed urceola of some rotifer, × 108.
g Surirella gemma, × 108.
h Do. do. × 65.
i Foraminifera, × 65.
j Trachleocerca linguifera, × 65.
k Small Planaria? ovisacs distended, × 65.
l Navicula viridis, × 285.
m Paramecium aurelia, × 170.
n Coleps hirsutus, × 285.
o Pleuronema crassa, × 285.
p Monura dulcis, × 170.
q Surirella splendida, × 170.
r Biddulphia pulchella, × 285.
s Surirella striatula, × 170.
t Rotifer, Monolabis conica? × 108.
u Aregma, spore cases, × 285.
v Stentor ceruleus? do. *v.* × contracted, × 170.
w Trinema acinus? × 170.
x Pinnularia grandis, × 170.
y Gyrosigma angulatum before dividing, × 170.
z Alyscum saltans? × 170.
aa Synedra ulna, × 170.
bb Amphiprora alata, × 285.
cc Gyrosigma Spencerii, × 285.
dd Nitzschia sigma, × 170.
ee Brachionus angularis, × 170.
ff Young Vorticella? × 170.
gg Gyrosigma fasciola, × 285.
hh Trachelius strictus, × 285.
ii Cocconema Boeckii, × 170.
jj Confervoid cell? with divided protoplasm, × 285.
kk Euplotes Charon, × 170.

(*To Binder—To face Plate II.*)

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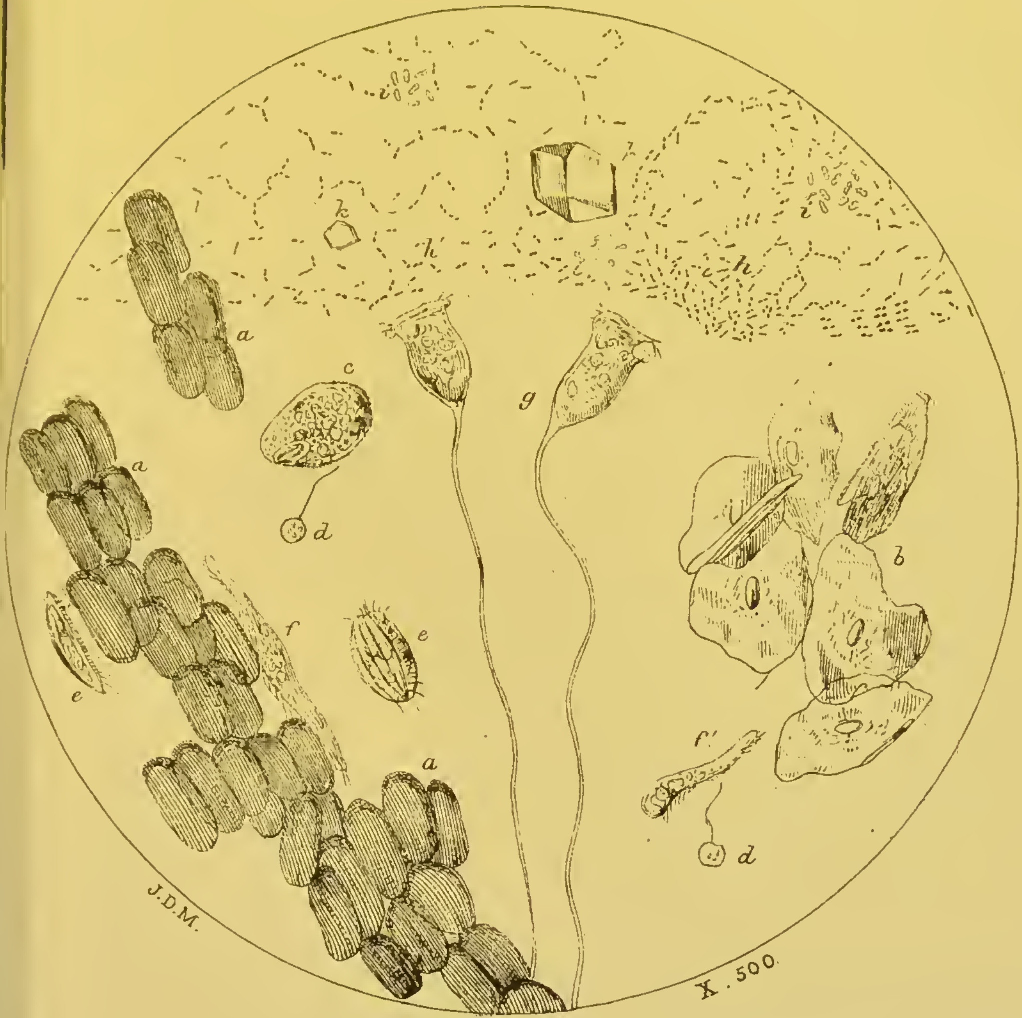
Description of Plate III.

Drawing of Sediment in Thames Water, taken just above Teddington Lock, in April 1878. Notice the evidence of impurities from men, viz., epithelium, woollen, cotton, and flax fibres.

Fig. 1. Coleps hirsutus.
2. Bodo grandis.
3. Actinophrys Eichornii.
4. Epithelium (tessellated).
5. Leucophrys striata.
6. Anguillula fluviatilis.
7. Paramecium chrysalis, dividing (? sexual stage).
8. Vorticella microstoma.
9. Kerona, young ?
10. Vorticella microstoma (stemless).
11. Paramecium aurelia.
12. Conferva.
13. Cocconema lanceolatum.
14. Synedra splendens.
15. Gyrosigma attenuatum.
16. Gomphonema acuminatum.
17. Wool fibre, dyed.
18. Cotton fibre, dyed.
19. Conferva floccosa.
20. Hair, barbed, of ?
21. Kerona mytilus.
22. Siliceous spicule.
23. Diatoma vulgare.
24. Fungi (? Torula).
25. Flax fibre.
26. Arthrodesmus quadricaudatus.
27. Stylonichia ? histrio, dividing.
28. Paramecium caudatum.
29. Woody fibre, ? rootlets.
30. Pollen.
31. Vegetable tissue and mycelium, with spores.
32. Decaying vegetable matter.
33. Gomphonema curvatum.
34. Spores of Fungi (? Aregma).
35. Antherozoid of ?
36. Encysted spore.

Decaying vegetable matter and infusoria abundant.

(To Binder—To face Plate III.)



References.

a. a. a. *Brown Vegetable cells. (probably Sporangial.) probably disengaged gonidia of lichens. (Leighton.)*

b. *Scales of Epithelium.*

c. *Glaucoma scintillans.*

d. *Monas lens.*

e. e. *Aspidisca denticulata, or Coccudina.*

f. f'. *Oxytricha gibba f'. young.*

g. *Vorticella Convalaria.*

h. *Bacterium termo in a broad sheet.*

i. *Localized groups of a larger form.*

k. *Crystalline particles, probably quartz.*

Then boil the water, and pour it back into the long glass. Sand, chalk, and heavy particles of the kind will be deposited; finely suspended sewage and vegetable matter is little affected, unless it be a chalk-water, when the deposit of calcium carbonate may carry down the suspended matter. When the water is commencing to boil, smell it to see if there is any trace of sewage.

Microscopic Examination.[1]

The examination with the microscope can, however, alone give accurate information of the nature of the suspended matters. Very high powers (1000 or 1200 diameters) are necessary for a complete examination, though lower powers will give much information.

If the matter is entirely suspended, a drop of the water must be taken at once; but when it can be obtained, a little of the sediment is more satisfactory. To get a sediment, the water should be placed in a conical glass (the space of which ought to be *rounded*, not *pointed*, at the bottom), carefully covered and allowed to stand for a few hours; and the upper part of the water is then poured away or siphoned off. In special cases, where it is important to know the exact condition of the suspended matters before they undergo change by the action of the atmosphere of the room or laboratory where they may be kept, they should be collected in vacuum tubes and sealed. A very small amount of sediment can be thus got at. An immense number of dead and living things are often found in water, which it would be impossible to enumerate, but which may be conveniently considered under two great and several minor divisions. The best kind of pipette for taking up the sediment for transfer to the glass slide is a plain straight tube, without bulb and without any narrowing to a point at either end; the diameter may be from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch ($1\frac{1}{2}$ to 3 millimetres).

1. *Inanimate Substances.*

(*a*) *Mineral particles* may be easily known; sand appears as large angular particles, often showing distinct conchoidal fracture; clay and marl as round smooth globules unaffected by acids; carbonate of calcium (chalk) sometimes smooth, but often crystalline, soluble in acids with effervescence. Iron peroxide appears in reddish-brown masses of an amorphous character; it is easily dissolved in hydrochloric acid, and strikes a deep blue with the ferrocyanide of potassium (yellow prussiate).

(*b*) *Vegetable matters:* portions of wood, leaves, bits of the veins, parenchyma, or ducts are easily recognised. When vegetable tissue is more decomposed nothing is seen but a dark, opaque, structureless mass. Any dark formless mass of this kind in water is almost certainly decayed vegetable matter. Bits of textile fabrics (cotton, linen) are not uncommon, and are important as indicating that the water is contaminated with house refuse. So also the cells of the potato, or spiral threads of cabbage and other vegetables used by man, are of value as indications of the same kind. Spiral cells are very indestructible, and are often found in river water to which sewage gains access.[2] Carbonaceous masses also occur, either portions of soot from coal smoke, or bits of charred wood. Sometimes fragments of

[1] For a good resumé of this part of the examination, reference may be made to Professor Macdonald's excellent work, *A Guide to the Microscopic Examination of Drinking-water*, by J. D. Macdonald, R.N., F.R.S., Inspector-General of Hospitals and Fleets, Professor of Naval Hygiene, Army Medical School, 2nd edition, Churchill.

[2] See Tidy's evidence, Report of Royal Commission on Metropolitan Sewage Discharge.

paper are met with, probably washed into the water from drains or cesspools.

(*c*) *Animal matters*, consisting of bits of wool, hair, and remains of animals of all kinds, such as wings and legs of insects, spiders and their webs, portions of the skin of water animals, or of fish, &c., are not uncommon. Sewage matters having a darkish-brown or reddish colour, and often in globular masses, and thus distinguishable from the flatter and more spread-out vegetable matter, are sometimes seen. In the London water, as supplied thirty years ago, Hassall recognised these little "ochreous" masses, and found that nitric acid brought out a pink tint. He thought them to be portions of muscular fibre, tinged with bile. Epithelium (from the skin of man)[1] and hairs of animals are not unfrequent. The identification of these matters is of moment, as indicating the particular source of the contamination. Anything which can be unequivocally traced to the habitations of man must always cause the water to be regarded with suspicion, as, if one substance from a house can find its way in, others may do so too.

2. *Living Organisms.*[2]

These are often found in the sediment, but sometimes also float in the water above the sediment. They are almost innumerable, and as immature forms and various stages of development are seen, it is often difficult or impossible to name all of them.

(*d*) *Bacteria, vibriones, or microzymes.*—Under these terms are meant the small points or jointed rods, sometimes moving rapidly, sometimes slowly or motionless. Distinctions are made between these three by some, while by others the three terms are used as synonyms.[3] High powers (and preferably with immersion lenses) are required to see them properly. When they appear in water it is necessary, as Lex[4] has shown, that besides oxygen three conditions must be present—(1) an organic carbonaceous substance; (2) a nitrogenous substance, which need not be organic—a nitrate, for example, will well nourish *bacteria*, and is reduced to nitrite by their growth;[5] (3) a phosphate, which, however, may be in exceedingly small quantity. The *bacteria* may either originally exist in the water, or be introduced. Burdon-Sanderson's experiments, however, are not favourable to the introduction of *bacteria* from the air, though large numbers of cells which seem to belong to the same class can be obtained from the air. It appears from Burdon-Sanderson's observations that the germs (if the term be allowed) of *bacteria* may exist in water and be indetectable by the highest microscopic powers, or even by Tyndall's test of the electric beam. To detect these the test by cultivation, or what may be called the *microzyme test for water*, can be employed. Take a little recently prepared clear Pasteur's fluid,[6] boil it, and put one or two c.c. into a test-tube previously strongly heated to 356° Fahr. (180° C.), drop in three or four drops of the

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[1] Epithelium from the skin breaks down slowly in water; soakage for many months does not destroy it. Epithelium from the mouths of cattle is sometimes found. This was the case in some water examined at Netley, got from a catch-pit in Parkhurst Forest.

[2] Numerous plates of the various organisms found in the Thames water have been given by Hassall. (*Microscopic Examination of the Water supplied to London*, by A. H. Hassall, M.D., 1860. *Food and its Adulteration*, by the same author, 1876.)

[3] Frequently spoken of as *Bacteroids*, and smaller forms as *Bacteriform puncta*.

[4] *Centralblatt für die Med. Wiss.*, No. 20, 1872, p. 305.

[5] Eventually the nitre disappears, nitrogen being liberated.

[6] Pasteur's fluid is composed of 10 grammes of crystallised sugar; 5 grammes of ammonium tartrate; 0·1 of well-burnt yeast ash, and 100 c.c. of distilled water. It should be quite clear. It is a capital breeding-ground for microzymes or fungi.

water, and close the mouth of the tube with cotton wool. If microzymes or their germs exist in the water, in a few days the liquid becomes milky from countless *bacteridia*.

As, however, even distilled water and the purest ice-water may contain *bacteridia*, the test cannot be used as a positive indication of good or bad water, except in connection with others, and with due regard to temperature, which has a great effect. All it will show is, that the greater or less rapidity of appearance of opalescence will prove that microzymes are more or less abundant.

At present there seems no reason to think that common (putrefactive) *bacteria* and *vibriones* are in themselves hurtful, but they indicate the existence of putrefactive organic matter, which is a danger. But there may be, and probably are, forms of *bacteria* which are more dangerous, and which may hereafter be distinctly differentiated by careful cultivation. For this purpose a sample of the water must be examined by mixing a small measured portion with gelatine (specially prepared) or other nutrient medium. This, when fluid, is poured over a glass plate, and set aside in a cultivating apparatus. In a day or two, colonies of minute organisms will show themselves. These can be counted by the microscope, and stated as so many per cubic centimetre. Note may also be taken of the characters of each, and whether or not they liquefy the medium. Separate pure cultivations can then be made in tubes to determine the exact nature of such as are doubtful. The significance of the different forms is as yet very obscure.

Both *spirillum* and *bacillus* can also be often detected in water. In addition to microzymes the water will always contain various allied *protista*, which are usually termed *monads* or *zooglœa*, and which seem to have the same significance as *bacteridia*.[1]

(*e*) *Fungi*.—In any water which contains nitrogenous matter (of animal nature, at any rate), sugar, and a little phosphate, *fungi* will soon appear, and the spores, no doubt, enter from the atmosphere. Spores, spore-cases, and delicate mycelium can be seen, and often *bacteridia* coexist. If *fungi* are found in water they indicate impurity, and such water should not be used if it can be avoided, or should be purified.[2] Boiling does not kill the *fungi*, according to Heisch; charcoal filtration does so, according to the same observer, though later experience has shown that this is not always the case. Animal charcoal adds some phosphate to the water, and in this way aids the growth of *fungi*. Spongy iron gives off no phosphate, and water filtered through it is quite free from *fungi*.

Heisch[3] states that sewage matter in water gives rise, when sugar is added to the water, to a peculiar *fungus*, which he describes as formed of very small, perfectly spherical transparent cells arranged in grape-like bundles; they grow rapidly into mycelia, and are attended with the special character of producing the odour of butyric acid. The mycelium soon disappears.

Dr Frankland doubts whether *fungi*, which are readily produced by adding sugar to sewage water, are distinctive of sewage, as apparently similar cells are caused by other animal matters.

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[1] According to Dr Macdonald, "All analogy would go to indicate that the Zooglœa form of *Bacterium termo* may be regarded as the primary or normal state of this organism, the surrounding gelatinous matter being simply the representative of that which forms the indefinite frond of *Microhaloa*, or *Palmella*, for example" (*op. cit.*, p. 14).

[2] In the cases of malarious fever at Tilbury Fort (*Army Med. Reports*, vol. xvii.) fungoid structures were found in the water whose use was coincident with the fever, but were absent from the water following on whose use the fever ceased.

[3] *Chemical News*, June 1870.

The identification of the spores of *fungi*, and even of the mycelium as seen in water, is so extremely difficult that it would be at present rash to affirm that any fungoid elements are distinctive of fæcal matter. The butyric acid smell also is given off by so many impure waters that it could hardly be used as a test for fæces.

(*f*) *Algæ, Diatoms, and Desmids* are found in almost all running streams, and are also seen in many well waters. They cannot be held to indicate any great impurity; and to condemn water on account of their presence would be really to condemn all waters, even rain, in which minute algoid vesicles (*protococci*) are often found.

The forms of the various *confervæ* in water are very numerous; some being coloured green, whilst at other times they are quite colourless, round, isolated, or clustered vesicles. The immature forms may not be easy of identification. The *Diatoms* are always readily recognised and identified. It may be stated generally that organisms of a grass-green colour, such as the green *algæ*, need not be objected to; but the bluish-green, such as the *Oscillatorians*, *Nostoc*, &c., are less desirable; not that they are probably directly injurious, but as indicating an impure water, and as being apt to give rise to an unpleasant ("pig-pen") odour. *Leptothrix ochræa*, which was at one time thought to be connected with a special disease poison, is really harmless, and is mostly found in waters containing a good deal of iron peroxide; such waters are usually singularly free from noxious organic matter.

(*g*) *Rhizopoda*, especially *amœbæ* and similar forms, may often be detected with high powers. They appear to indicate, like *bacteridia*, the existence of putrefying substances, but this is not yet certain. They are not found in first-class waters.

(*h*) *Euglenæ* (of different species, such as *E. viridis*, *E. pyrum*, &c.) are found in many waters, especially of ponds and tanks.[1] Ciliated, free, and rapidly moving *infusoria*, belonging to several kinds of common *protozoa*, such as *kolpoda*, *paramecium*, *coleps*, *stentor*, *kerona*, *stylonychia*, *oxytricha*, &c., are also found. The peculiar red colour of some waters, such as that of the river Itchen at Southampton in summer, is due to *Peridinium fuscum*, as first pointed out by Professor Macdonald, F.R.S. The abundance of these bodies indicates, of course, that the water contains food for them, and this must be either vegetable or animal organic matter, but the mere presence of these *infusoria* will not show which it is. Hassall noticed, however, in 1850, that the Thames water below Brentford, where it was mixed with sewage, swarmed with *paramecia*, while at Kew, where the water was freer from sewage matters, they had almost disappeared. Subsequent observations have not, however, proved the relation between *paramecia* and animal matter in the water to be sufficiently constant to allow the former to be used as a test of the latter. Fixed or slow moving *infusoria*, as the *vorticellæ*, are also often seen in river waters.

In many waters the living objects in the above five classes comprise all that are likely to be seen, but in the other cases there are animals of a larger kind.

(*i*) *Hydrozoa*, especially the freshwater *polyps*, are common in most still waters, and do not indicate anything hurtful.

(*k*) *Worms*, or their eggs and embryos, belonging to the class *Scolecida*, may occur in water, and are of great importance. The eggs and joints of the tapeworm, the embryos of *Bothriocephali*, the eggs of the round and thread

[1] There appears reason to believe that all or most of the flagellate animalcules are vegetable, and the minuter (such as *monas*) are probably connected with the reproduction of higher forms, such as *fungi*.

worms, and perhaps the worms themselves, the Guinea-worm, and other kinds of *Filaria*; the eggs of *Dochmius duodenalis*, and other *distomata*, and the embryos of *Bilharzia*, have all been recognised in water, though it has not yet been shown that in all cases they can be thus introduced into the human body. That *Filaria sanguinis hominis* may be taken in drinking water is most probable, seeing that its host, the mosquito, is developed in water, the larvæ of the latter being found in great quantity in tanks and cisterns. Worms themselves cannot well be overlooked, but both eggs and the free-moving embryos are sometimes difficult of identification. The greatest care should be used in examining water to detect ova. In India, the abundance of minute *Filariæ* has led to the general term of "tank worm" being applied.

The presence of even common *Anguillulæ* in water shows generally an amount of impurity, and such a water must be regarded with great suspicion. Small leeches also are not uncommon in both still and running waters.

The wheel animalcules are common enough, and cannot be regarded as

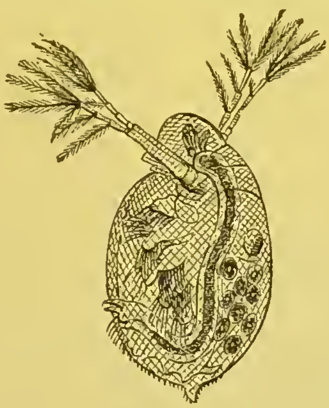

Fig. 102.

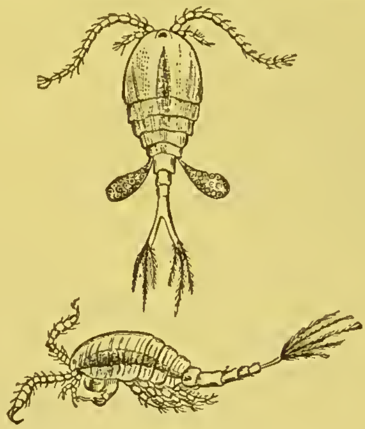

Fig. 103.

very important, though certainly when they exist there must be a good deal of food for them, and consequently impurity of water.

(*l*) *Entomostraca* (such as the water flea, *Daphnia pulex*, fig. 102; *Cyclops quadricornis*, fig. 103; *Sida*, *Moina*, *Polyphemus*, and others) are very common in the spring; they occur in so many good waters that they cannot be considered as indicating any dangerous impurity. It is said that they are only found near (within one or two feet) of the surface. *Amphipoda* (*Gammarus pulex*) may also be met with, as well as *Isopoda* (*Asellus aquaticus*) and *Tardigrada* (water bears), especially if water that has been stagnant gets washed into tanks, cisterns, or water butts.

(*m*) There are, of course, many other tolerably large animals often found in water; the larvæ of the water beetle (*Dytiscus*), the water boatman or skipjack (*Notonecta glauca*), and the pupa form of many insects, may be found, but they are chiefly in pond water.

So many are the objects in water that the observer will be often very much at a loss, first, to identify them, and secondly, to know what their presence implies. The best way is first to see what objects appear to be mineral, or non-living vegetable substances, and to fix the origin and estimate the quantity as far as it can be done. Then to turn to the living organisms and to look attentively for *bacteridia*, *amœbæ*, *fungi*, and *ova*, and small worms and leeches. If none of these exist, and if cultivations show the water to be fairly free from microzymes, the water cannot be considered dangerous. Ciliated *infusoria* of various kinds, and *Diatoms*, *Desmids*, and *Algæ*, are chiefly important in connection with microscopic evidence of

decaying vegetable matters, and with chemical tests showing much dissolved organic impurity in the water.

The subjoined plates show the principal objects found in a deep-well water (Plate I.); in a slow running stream (Plate II.); in Thames water taken in 1868 above Teddington Lock (Plate III.); in water from a spring near Railway at Tilbury (Plate IV.).

Chemical Examination of the Sediment.

The amount of sediment is told by taking two equal quantities of water (say ½ litre), evaporating one quantity to dryness at once, and the other after subsidence or filtration, so that suspended matters are as far as possible separated, and then weighing the two residues. The difference between the two weights gives the amount of the sediment. Or a certain amount of water may be allowed to stand until all the sediment has fallen; the water is poured off, and the sediment dried and weighed. If good Swedish filtering paper is obtainable, the sediment may be obtained at once; two filters should be moistened with dilute hydrochloric acid, then washed with distilled water and then dried. The amount of ash in one filter should then be determined by incineration; the sediment should be collected on the other filter, dried, weighed, and then incinerated. The ash of the filter itself being known, the weight of the ignited sediment is the total weight, less the ash of the filter. If it be wished to carry the analysis farther, the sediment is incinerated; mineral matter remains, while all animal and vegetable matter, whether previously inanimate or living, is destroyed. This matter of such various origin is generally stated under the vague terms of organic or volatile matter, but this gives no idea of its origin. Some of this so-called organic matter may have been dead, another portion living. The mineral may be further determined by digesting in weak hydrochloric acid by the aid of heat; the undissolved matters are silica and aluminum silicate; lime, iron, and magnesia will be dissolved, and can be tested for as hereafter given.

SECTION III.

Examination of Dissolved Matters.

In all examinations of water, if the sediment is not expressly referred to, it is to be understood that the examination refers *only* to the dissolved matters. These are gases or solids.

Gases.—Oxygen, nitrogen, carbon dioxide, hydrogen sulphide, and carburetted hydrogen are the most usual gases. If the three former coexist, as is generally the case, the oxygen is usually in larger relative amount than in atmospheric air, as it often reaches 32 per cent.[1] The amounts of oxygen and carbon dioxide depend so much on varying conditions, such as the amount of exposure to the air, the growth or absence of plant life, and the presence of animals, as to render the proportions, absolute and relative, of the gases so variable, that few inferences of hygienic importance can be drawn from their determination. A lessening, however, at one part of its course, in the quantity of oxygen which a certain water is known to contain, may be useful, as pointing out that organic matter has been in the water.[2]

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[1] Atmospheric air, according to Bunsen's coefficients of absorption, would dissolve in water in the proportion of 65·1 of nitrogen and 34·9 of oxygen.—Wanklyn, *Water Analysis*, p. 103.

[2] Up till recently Gérardin considered that the degree of oxygen (oxymétrie) was the best

Thus Professor Miller found that Thames water contained the following amount of gases in c.c. per litre, in its flow down stream :[1]—

	Kingston.	Hammersmith.	Somerset House.	Greenwich.	Woolwich.
Carbon dioxide,	30·3	...	45·2	55·6	48·30
Oxygen, .	7·4	4·1	1·5	0·25	0·25
Nitrogen, .	15·0	15·1	16·2	15·4	14·50

The stability of the nitrogen, the increase in the CO_2, and the lessening of the oxygen, are well seen. If water contain much CO_2, bubbles of the gas form on the sides of the glass in which the water is placed. So far as our knowledge extends at present, there seems to be but little information obtained by the determination of the amount of gases in water; but if it is decided to do so, we require a mercurial trough, a graduated tube-measure to be filled with mercury and inverted into the trough, a flask and a connecting tube with a bulb blown on it. The flask is filled with water, and connected with the bulb-tube by an india-rubber tube, which is to be closed by a clamp. Some water is put into the bulb, and boiled; this is to expel air from the connecting tube; and when this is done, the end of the tube is put into the mercurial trough under the vessel filled with mercury, the clamp is removed from the india-rubber tube, and the water is cautiously boiled for an hour. The gases collect in the mercurial tube, and are measured (due regard being had to temperature and pressure, and the other corrections); the CO_2 is absorbed by potash, the oxygen by potassium pyrogallate, and the nitrogen is read as the residue.

As regards the CO_2, there is an objection to this method, as the heat decomposes the calcium and magnesium bicarbonates, and therefore the amount of CO_2 evolved is greater than existed in the water as free carbonic acid. On the other hand, it is impossible by heat alone to obtain all the oxygen and nitrogen.[2]

As this operation is rather a delicate one, and requires some practice, and as the information it gives, in a hygienic point of view, does not appear to be so useful as that obtained by other methods, it may be omitted except in cases where the amount of aëration is considered very important. The amount of free CO_2 can also be determined approximately by the soap solution subsequently described. Dr Macnamara has proposed[3] a still simpler method for the examination of water in India.

Dr Frankland has proposed a very ingenious plan for extracting the gases from water without heat. It is an application of the Sprengel pump, in which the Torricellian vacuum of a barometer is made to act as an air-pump. The gases can be extracted either at the ordinary or boiling temperature. This plan may be useful in laboratories where much water

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test of a water's purity. He has since modified this view considerably. The importance of the indication is also greatly lessened by the fact that deep well waters, of undoubted potable excellence, yield extremely little oxygen,—often not more than the Thames at Woolwich.

[1] In the report of the Royal Commission on Metropolitan Sewage Discharge will be found a large number of determinations of the gases, showing the absorption of oxygen by the organic matter of the sewage. The condition of the river is such that no fish can live between Greenwich and Gravesend.

[2] The plan of determining the oxygen by means of the sodium hydrosulphite, suggested by Schützenberger and Gérardin, is ingenious and rapid, but it has the inconvenience of requiring the reagent to be freshly prepared, as it will not keep. (See *Comptes Rendus de l'Académie des Sciences;* Lefort, *Traité de chimie hydrologique; Annales d'Hygiène,* Janvier 1877).

[3] *Scheme of Water Analysis for India.*

analysis is carried on, but it can hardly at present be applied by army medical officers.

Hydrogen sulphide sometimes occurs in water as a consequence of the decomposition of sulphates by organic débris, even by the cork of the bottles, the SH_2 being afterwards liberated by carbonic acid. In some mineral waters (Marienbad) hydrogen sulphide appears when *algæ* are in the water, but not without.[1]

If the gas is present in any quantity, it can be detected by the smell. Alkaline sulphides have, however, less smell. Both, even without smell, can be detected by salts of lead. A large quantity of water should be taken in an evaporating dish, and a little clear lead subacetate or acetate allowed to flow tranquilly over the surface. Black fibres of lead sulphide are formed. If lead acetate is mixed with solution of soda until the precipitate which at first forms is redissolved, a very delicate test-liquor is obtained. Solution of sodium nitro-prusside is also a delicate test, and gives a beautiful violet-purple colour. As it acts only on the alkaline sulphides, a little solution of soda or ammonia must also be added to detect the free hydrogen sulphide.

Carburetted hydrogen in small quantity in water is not readily detected, but Tiemann says that warming the water to 110° Fahr. (44° C.) will enable the smell to detect coal-gas, when chemical reagents fail. Generally there are other impurities, especially if it be derived from gas impregnation. In larger quantity it sometimes bubbles up from the water of stagnant pools, particularly if there be much vegetable matter; and, in the cases of some natural springs in petroleum districts, can be ignited.

Dissolved Solids.

The chemical examination of the dissolved matters is divided into the *qualitative* and the *quantitative.*

Qualitative Examination of Dissolved Solids.

The water may be either at once treated, or, in the case of some constituents, it should be concentrated by evaporation.

Water not Concentrated.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Reaction.	*Litmus* and *turmeric* papers; usual red or brown reactions.	Usually neutral. If acid, and acidity disappears on boiling, it is due to carbonic acid. If alkaline, and alkalinity disappears on boiling, to ammonia (rare). If permanently alkaline, to sodium carbonate.
Lime.	*Oxalate of Ammonium.* White precipitate.	Six grains per gallon (9 per 100,000) give turbidity; sixteen grains (23 per 100,000) considerable precipitate.
Chlorine.	*Nitrate of silver*, and *dilute nitric acid.* White precipitate, becoming lead colour.	One grain per gallon (1·4 per 100,000) gives a haze; four grains per gallon (6 per 100,000) give a marked turbidity: ten grains (14 per 100,000) a considerable precipitate.

[1] *Archiv für Wiss. Heilk.*, 1864, No. III. p. 261.

Water not Concentrated—continued.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Sulphuric Acid.	*Chloride of barium* and *dilute hydrochloric acid.* White precipitate.	One-and-half grains (2 per 100,000) of sulphate give no precipitate until after standing; three grains (4 per 100,000) give an immediate haze, and, after a time, a slight precipitate.
Nitric Acid.	*Brucine* solution[1] and *pure sulphuric acid.* A pink and yellow zone.	The sulphuric acid should be poured gently down to form a layer under the mixed water and brucine solution; half a grain of nitric acid per gallon (=0·7 per 100,000) gives a marked pink and yellow zone; or, as recommended by Nicholson, 2 c.c. of the water may be evaporated to dryness; a drop of pure sulphuric acid and a minute crystal of brucine be dropped in; 0·01 grain per gallon (=0·0143 per 100,000) can be easily detected.
Nitrous Acid.	*Iodide of potassium*[2] and *starch* in solution and *dilute sulphuric acid.* An immediate blue colour.	Add the solution of iodide of potassium and starch, and then the acid; the blue colour should be immediate; make a comparative experiment with distilled water.
	Solution of *meta-phenylene diamine* and dilute *sulphuric acid* (Griess's test)—a yellow colour more or less immediate according to amount of nitrous acid.	This is a very delicate test; a yellow colour will appear in the water in half an hour, if there be only one part of nitrous acid in 10,000,000 of water.
Ammonia.	*Nessler's* solution.[3] A yellow colour or a yellow-brown precipitate.	If in small quantity, several inches in depth of water should be looked down through on a white ground.
Iron.	*Red* and *yellow prussiates of potash,* and *dilute HCl.* Blue precipitate.	The red for ferrous and the yellow for ferric salts.
Hydrogen Sulphide.	A salt of *lead.* Black precipitate.	When the water is heated the smell of hydrogen sulphide may be perceptible.
Alkaline Sulphides.	*Nitroprusside of sodium.* A beautiful violet-purple colour.	A black precipitate with lead, but no colour with nitroprusside shows that the hydrogen sulphide is uncombined.
Oxidisable matter, including organic matter.	*Gold chloride.* Colour varying from rose-pink through violet to olive; a dark violet to black precipitate.	The water, which should be neutral or feebly acid, must be boiled for 20 minutes with the gold chloride. If no nitrous acid be present, the reaction may generally be considered due to organic matter.

[1] See Appendix A. [2] See Appendix A. [3] See Appendix A.

Water not Concentrated—continued.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Oxidisable matter, including organic matter.	Note the darkening of the *silver chloride* in testing for chlorine.	Compare with a precipitate produced in a pure solution of a chloride.
Lead or Copper.[1]	*Ammonium sulphide.* Dark colour, not cleared up by hydrochloric acid.	Place some water (100 c.c.) in a white dish, and stir up with a rod dipped in ammonium sulphide; wait till colour produced, then add a drop or two of hydrochloric acid. If the colour disappears, it is due to iron; if not, to lead or copper.[2]
Zinc.	*Hydrogen sulphide.* A white precipitate. If zinc be in considerable quantity, it is generally present as bicarbonate, and gradually forms a film of carbonate on the surface of the water. This film may be collected and heated on platinum foil. If the residue remain yellow when hot and white on cooling, the presence of zinc is indicated. This reaction is very delicate.[3]	This test is not available if there be iron present, should the water be alkaline. It forms, however, in perfectly neutral waters, but not in acid. A little *acetate of sodium* greatly aids this; or *ammonium sulphide* with an alkaline solution in excess; or acidulate water with *hydrochloric acid* and add *potassium ferrocyanide*; a white precipitate appears, pale greenish if there be iron in the hydrochloric acid.

Water Concentrated to $\frac{1}{50}$th (in a porcelain dish).

Substance sought for.	Reagents to be used, and effects.	Remarks.
Magnesia.	*Oxalate of ammonium* to precipitate lime, then after filtration a few drops of *phosphate of sodium*, of *chloride of ammonium*, and of *liq. ammoniæ.* A crystalline precipitate in 24 hours.	A precipitate forms in 24 hours, and is the triple phosphate either in the shape of prisms or in feathery crystals.
Phosphoric Acid.	*Molybdate of ammonium* and *dilute nitric acid.* A well-marked yellow colour, and on standing a precipitate.	Add the nitric acid, and stir with a glass rod, then add twice the quantity of molybdate and boil.

[1] Sidney Harvey (*Analyst*, vol. vi. p. 146) recommends small crystals of potassium bichromate. According to him $\frac{1}{10}$ of a grain per gallon gives an immediate turbidity, $\frac{1}{20}$ after 15 minutes, and $\frac{1}{50}$ after 30 minutes. These numbers equal, respectively, 0·14, 0·07, and 0·03 per 100,000.

[2] Wanklyn.

[3] Frankland, *Water Analysis*, 1880, p. 44.

Water Concentrated to $\frac{1}{50}$th (in a porcelain dish)—continued.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Nitric Acid.	*Brucine* test.	If the nitric acid is in small quantity, it may not be detected in the unconcentrated water.
Silicic Acid.	Evaporate to dryness, moisten with *strong hydrochloric acid;* after standing, add boiling distilled water; pour off fluid; dry, ignite; repeat the treatment with hydrochloric acid and water; dry, ignite again, and the residue is silica, or silicate of aluminum.	The residue may be weighed, and thus the silica determined quantitatively. A little clay or oxide of iron will be sometimes mixed with it.
Lead or Copper.	As before.	If quantity be very small.
Arsenic.	*Marsh's* or *Reinsch's* tests.	Water should be rendered alkaline with *sodium carbonate* before concentration, then acidulated with *hydrochloric acid.*
Zinc.	Evaporate to dryness; treat residue with *caustic potash* or *ammonia*, filter and test filtrate with *hydrogen sulphide;* a white precipitate falls.	This is necessary if the quantity be small, or if iron be present. If a film of carbonate forms on concentration, it may be tested on platinum foil, as before described.

Inferences from the Qualitative Tests.

Sometimes no time can be given for quantitative determinations, and the qualitative tests are the only means available by which the question so constantly put, whether a water is wholesome or not, can be in some degree answered.[1]

If chlorine be present in considerable quantity, it either comes from strata containing chloride of sodium or calcium, from impregnation of sea-water, or from admixture of liquid excreta of men and animals. In the first case the water is often also alkaline, from sodium carbonate; there is an absence, or nearly so, of oxidised organic matters, as indicated by nitric and nitrous acids and ammonia, and of organic matter; there is often much sulphuric acid. These characters are common in deep-well waters. If it be from calcium chloride, there is a large precipitate with ammonium oxalate after boiling. If the chlorine be from impregnation with sea-water, it is often in very large quantity; there is much magnesia, and little evidence of oxidised products from organic matters. If from sewage, the chlorine is marked, and there is coincident evidence of nitric and nitrous acids and ammonia, and sometimes phosphoric acid; and if the contamination be recent, of oxidisable organic matters. A stream fouled by animals or excreta may thus show at different times of the same day different amounts of chlorine, and this, in the absence of rain, will indicate contamination.

[1] Kubel and Tiemann rely very greatly on the qualitative tests.

Ammonia is almost always present in very small quantity, but if it be in large enough amount to be detected without distillation it is suspicious. If nitrates, &c., be also present, it is likely to be from animal substances, excreta, &c. Nitrates and nitrites indicate previously existing organic matters, probably animal, such as excreta, remains of animals, &c.;[1] but nitrates may also arise from vegetable matter, although this is probably less usual. If nitrites largely exist, it is generally supposed that the contamination is recent. The coincidence of easily oxidised organic matters, of ammonia, and of chlorine in some quantity, would be in favour of an animal origin. If a water gives the test of nitric acid, but not nitrous acid, and very little ammonia, either potassium, sodium, or calcium nitrate is present, derived from soil impregnated with animal substances at some anterior date.

Tabular View of Inferences to be drawn from Qualitative Examination.

Chlorine.	Oxidisable matter by Gold Chloride or Silver Chloride.	Nitrates.	Nitrites.	Ammonia.	Phosphates.	Sulphates.	Classification of Water.	Remarks.
Slight.	Slight.	Nil.	Nil.	Nil.	Nil.	Trace.	Good.	A perfectly pure water.
Marked.	Nil or trace.	Nil.	Nil.	Marked.	Present.	Trace.	Good.	A good water, probably from a deep well.
Marked.	Slight.	Marked.	Nil or trace.	Trace.	Trace.	Trace.	Usable.	Probably old animal contamination.
Large.	Slight.	Nil or trace.	Nil.	Nil.	Nil or trace.	Marked.	Usable.	Probably some contamination with sea-water.
Slight.	Well marked.	Marked to large.	Nil.	Nil.	Nil or trace.	Nil or trace.	Usable.	Probably vegetable impurity: peat?
Marked.	Nil or trace.	Marked.	Nil or trace.	Marked.	Marked.	Marked.	Suspicious.	Probably a shallow well, contaminated with urine.
Slight.	Marked.	Present.	Present.	Marked.	Trace.	Trace.	Impure.	Probably water contaminated with sewer gases.
Marked.	Large.	Marked.	Marked.	Marked.	Marked.	Marked.	Impure.	Water contaminated with sewage.

If nitrites are present at first, and after a few days disappear, this arises from continued oxidation into nitrates; if nitrates disappear, it seems probable this is caused by the action of *bacteria*, or other low forms of life. Sometimes in such a case nitrites may be formed from the nitrates. Phosphoric acid, if in any marked quantity, indicates origin from phosphoric strata (which is uncommon) or sewage impregnation. Wanklyn has ridiculed the idea of phosphoric acid being present in any appreciable quantity in water, if (as is almost always the case) lime be also present. But, independent of the fact that the reaction of phosphoric acid is obtained in water,

[1] Dr Frankland has considered these substances as the representatives of "previous sewage contamination." In many cases they are so, but it cannot be held that they are always so; any nitrogenous substance, quite apart from sewage, may furnish them, so that the phrase has been objected to, and is better avoided.

Hehner[1] has clearly shown that phosphoric acid does exist in appreciable quantity as phosphates, especially in polluted waters. Lime in large quantity indicates calcium carbonate if boiling removes the lime; sulphate, chloride, or nitrate if boiling has little effect. Testing for calcium carbonate is important in connection with purification with alum. Sulphuric acid in large quantity, with little lime, indicates sulphate of sodium, and usually much chloride and carbonate of sodium are also present, and on evaporation the water is alkaline. Large evidence of nitric acid, with little evidence of organic matter, indicates old contamination; if the organic matter be large, and especially if there be nitrous acid as well as nitric present, the impregnation is recent. It may also indicate the absence of the nitrifying ferment from the water.

To the above qualitative tests would, of course, be added the physical characters, which would to some considerable extent influence the conclusions to be drawn. When possible, the microscopic appearances ought also to be carefully noted, as the presence of such substances as epithelium, house refuse, &c., will sometimes justify us in condemning a water which may appear chemically only suspicious.

A water containing in appreciable quantity any metal (except iron), other than the alkaline and earthy metals, is to be condemned.

A water containing any gas other than oxygen, nitrogen, or CO_2, is to be considered suspicious, and not to be used without boiling or filtration, or both.

Quantitative Examination of Dissolved Solids.

The discrepancies which are sometimes found in the consecutive analyses, or in analyses by two observers of the same water, probably often arise from the difficulty of always separating the suspended matters. Consequently two samples, apparently similar, may in reality contain variable quantities of suspended matters which affect the determination of the solids, or influence other tests.

To avoid this source of fallacy, if the water be sedimentous, the portion to be examined for solids should be placed in a well-stoppered bottle in a dark place for twenty-four or forty-eight hours, until all sediment has subsided, and the clear water should be then siphoned off. If the sediment is too fine to subside, the water must be filtered through paper (previously well washed with weak hydrochloric acid, and then with distilled water, and then dried), but if possible filtration should be avoided.

Of the solids in water some are mineral, and derived from the mineral constituents of the soil, such as lime, magnesia, and part of the chlorine, and of the sulphuric, carbonic, and silicic acids; others are also inorganic, but are derived from the remains of animals or vegetables, by oxidation or solution, or from the atmosphere, such as ammonia, nitric acid, nitrous acid, some of the chlorine, and of the sulphuric and phosphoric acids. Other constituents, derived from numerous sources, are vegetable or animal matters, which are usually unstable, and are undergoing disintegration and oxidation. They may be nitrogenous or not. The composition of these substances is doubtless extremely various; the determination of the total quantity is difficult; the separation of the different kinds from each other, at present, impossible.

The methods by which the quantity of this organic matter (to use its

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[1] *Analyst*, vol. v. p. 135.

familiar name) can be expressed have been lately much debated, and even now there is no general agreement;[1] nor, at present, is there any plan by which dissolved vegetable may be distinguished from animal matter, except by reference to the microscopic characters of the sediment, to the source of the water, and the coincident inorganic substances.

The quantitative processes which appear, in a hygienic sense, to be most useful are as follows :—

Determination of—

1. *Dissolved solids.* (*a*) Total. (*b*) Fixed. (*c*) Volatile.
2. *Chlorine.*
3. *Hardness.* (*a*) Total. (*b*) Fixed. (*c*) Removable.
4. *Free or saline ammonia and nitrogenous organic matter.*
   (*a*) *Free* ammonia.
   (*b*) *Albuminoid* ammonia.

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[1] The following plans have been tried at successive times :—

1. The estimation by ignition of the dried solids. However useful ignition is as indicating the presence of nitrites, nitrates, or organic matter, the results are very uncertain as regards quantity, owing to the loss of hygroscopic water, the decomposition of carbonates, and errors arising in recarbonating, the loss of nitrites and nitrates, and in some cases of chlorine, as well as the destruction of organic matter. Hence "substances driven off by heat," or "volatile substances," is not an equivalent expression for "organic matters."

2. Precipitation by perchloride of iron, weighing, incinerating, and weighing again. The difficulty here is that all the organic matter is not precipitated, and other mineral substances may be.

3. The determination of the nitrogen and carbon in the organic substances. This is the plan proposed by Dr Frankland, who determines the nitrogen in the ammonia, nitric and nitrous acids which may be present, and also that in organic combination, and in this way gets at the nitrogen, which must have formed part of the organic matter ("organic nitrogen"). In the same way the carbon existing other than in the shape of carbonic acid is determined ("organic carbon"). He has proposed a most ingenious and beautiful process, the most recent and best account of which is contained in his *Water Analysis for Sanitary Purposes*, 1880, p. 59. This plan requires so much apparatus, time, and skill as to be quite beyond the reach of medical officers, and it would also appear that in the hands of even very able chemists it gives contradictory results; the quantities are in fact so small, and the chances of error so repeated, that in its present form this really beautiful plan seems not adapted for hygienic water analysis. It is also difficult to know what construction should be put on the results; a water containing much non-nitrogenous organic matter may give a very much larger amount of "organic carbon" than a water containing a much smaller amount of nitrogenous matter, and yet be much less hurtful.

4. The determination of the nitrogen of the organic matters (as ammonia) by means of alkaline permanganate of potassium ("albuminoid ammonia"), after all ammonia existing as such in the water has been got rid of. This plan, proposed by Wanklyn and Chapman, has the merit of simplicity and rapidity. It has been objected to by Frankland on the ground that the whole of the nitrogen is not obtained. There is no doubt of this; but Wanklyn affirms that the quantity obtained is constant, and therefore comparison between different waters can be instituted. Thudichum and Dupré, in their work on *Wine* (p. 262), state that they find the albuminoid ammonia process so accurate for albumen in wine, that they use it in preference to other methods. It must be confessed that this point has not been probed to the bottom, and that especially the relation of the "albuminoid ammonia" to disease produced by the water has not been yet made out. The "albuminoid ammonia" of pure potable water has been simply taken as a standard, and the wholesomeness of other waters judged of by reference simply to this. But at the present time it is the most convenient process we have, and (with some reservation as to the precise inferences to be drawn from it) it has been pretty generally adopted.

5. Two other processes, that of Dittmar and Robinson, and that of Dupré and Hake, are described in Frankland's *Water Analysis*, but neither seems adapted for the use of medical officers.

6. Estimation of the organic matter in terms of the oxygen required to oxidise it, the permanganate of potassium being the oxidising agent. This process (originally proposed by Forchammer of Copenhagen) has been much used and much objected to, and some chemists have now given it up. It gives, certainly, only an approximation, requires care, and will only indicate the organic matter capable of oxidation. Yet it gives really useful information, as it often adds additional evidence to Wanklyn's method, and gives some indication as to the old or recent origin of nitric acid, and is easy of application. The objections urged against it by Frankland have been recently modified, and it is acknowledged as a process of value, when properly applied. It would be very undesirable to discontinue it; and in those cases where, from want of apparatus, the distillation necessary for Wanklyn and Chapman's method

5. *Oxidisable matter and products of organic oxidation.*
   (*a*) In terms of *oxygen* required for *total oxidisable matter.*
   (*b*) In terms of *oxygen* required for *organic matter* only.
   (*c*) *Nitrous acid.*
   (*d*) *Nitric acid.*
6. *Phosphoric acid* in phosphates.
7. *Sulphuric acid, silica, iron,* and the *alkaline carbonates* may be determined, but are seldom required.

The statement of results is usually given in this country in grains per gallon, or in parts in 100,000; or it may be given in grammes per litre, which is the same as parts per 1000, and by shifting the decimal point to the right, parts per 10,000, 100,000, or per 1,000,000 are obtained.[1] It is much to be desired that one uniform mode should be definitively adopted, in order to avoid the confusion which at present undoubtedly exists in this country. In this work the denomination will generally be parts per 100,000 (centigrammes per litre).

1. *Determination of the Dissolved Solids.*

(*a*) *Total solids.*—The remark already made about suspended matters must be attended to; if possible, obtain a clear water by subsidence rather than by filtering through paper. The solids are determined by evaporation. If very good scales are available, 200 c.c. of the water are sufficient,[2] if the scales are inferior, 500 or 1000 c.c. of the water must be taken; then evaporate to dryness with a moderate heat, taking care that the water does not boil, else there may be loss from spurting. If the smaller quantity be taken, the whole evaporation may be conducted in one vessel (of platinum, if possible); but if the larger amount must be used the evaporation should be commenced in a large evaporating dish, and the concentrated water and deposit, if any, transferred into a small weighed crucible. The transference demands great care, so that none of the solids shall remain encrusted in the evaporating dish. All the contents of the large dish being transferred, evaporate to complete dryness in air, water, or steam bath, at 212° Fahr. (100° C.). Weigh as soon as the capsule is cold, as the dried mass may be hygroscopic. It may be necessary to replace it in the bath and weigh again after an interval of half an hour. If there is no material difference the drying is completed.

Professor Wanklyn advises a very simple form of steam bath. A common two-gallon tin can is taken, a perforated cork fitted in the mouth, and a funnel passed through the perforation; the crucible is placed in the funnel, a little roll of paper being placed between the funnel and crucible to let the steam pass. Water is boiled in the tin can.

Bischof's bird-fountain apparatus is very convenient for evaporation.

Dr Frankland recommends that the heat shall not be carried above 212°

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cannot be done, it is at present absolutely essential. Kubel and Tiemann reject both Frankland's and Wanklyn's methods as untrustworthy, and trust to modifications of the permanganate process. For further discussion of the subject, see under "Organic matter," later on.

[1] Grammes per litre are converted into grains per gallon by multiplying by 70. Milligrammes per litre, if multiplied by ·07, are brought into grains per gallon. Grains per gallon are converted into parts per 100,000 by dividing by ·7; parts per 100,000 are brought into grains per gallon by multiplying by ·7.

For equivalents of the metrical weights, see Appendix B.

[2] Wanklyn recommends a "miniature gallon" of 70 c.c., which, he says, evaporates in one hour. This is too small a quantity to work on. Becker of Rotterdam has introduced very good scales at a low price.

Fahr. (100° C.), while some chemists advise a heat of over 300° (149° C.). At 212° (100° C.) sufficiently complete drying can be obtained by prolonged exposure, whilst at the higher temperature we risk destroying the organic matter.

The S.P.A. recommend evaporating first in a water bath, then drying the residue at 220° Fahr (104°·5 C.), and finally cooling under a desiccator.[1] It would be well not to exceed 220° Fahr. (104°·5 C.).

The determination of the total solids is an important point, and should be carefully done. It gives a control over the other quantitative determinations, and if erroneous may make the other conclusions wrong.

(*b*) *Fixed Solids.*—Incinerate the dried solids at as low a heat as possible; watch the process, and note if there be much blackening, or if any fumes can be seen, or any smell be perceived as of burnt horn. A piece of filtering paper dipped in solution of potassium iodide and starch, and then dried, or a piece of ozone paper, should be held over the crucible to detect any nitric oxide which may be given off.

(*c*) *Volatile Solids.*—The loss on ignition may be stated as "volatile substances." It consists of destructible organic matters, nitrates, nitrites, ammoniacal salts, combined water, combined carbonic acid,[2] and sometimes chlorides. The variableness of the composition of the "volatile substances" has led to the disuse of the process by ignition as too uncertain. Combined with other evidence it gives, however, some useful indications. The incinerated solids may be examined for silica and iron, as hereafter noted.

The statement of the results may be given in various ways, as before mentioned, but the ratios most used nowadays are parts in 100,000 (equal to *centigrammes* per *litre*) or *grains* in a *gallon* (equal to parts in 70,000).

Example.—1. *Total solids.*—200 c.c. dried as described :—

Weight of dish and residue, . . .	19·27 grammes.
„ of dish alone, ...	19·23 „
Difference, . .	0·04

being grammes of total solids in 200 c.c. of water.

To bring to centigrammes per litre, or parts per 100,000:

$0·04 \times 500 = 20 =$ centigrammes per litre, or parts per 100,000.

To bring to grains per gallon :

$20 \times 0·7 = 14·0$ grains per gallon.

2. *Fixed solids.*—The above residue is incinerated, and the CO_2 restored to the earthy carbonates if required.

Weight of incinerated residue and dish,	19·26
„ of dish alone, ...	19·23
Difference, being grammes of fixed solids in 200 c.c. of water, ...	0·03

$0·03 \times 500 = 15$ parts per 100,000.

$15· \times 0·7 = 10·5$ grains per gallon.

[1] Tiemann recommends 150° to 180° C., equal to 302° to 356° F.

[2] This may be partly restored by adding a little saturated solution of ammonium carbonate, and then drying and driving off the excess of ammonia.

3. *Volatile solids* :—

		Parts per 100,000.	Grains per gallon.
Total solids,	=	20·0	14·0
Fixed ,,	=	15·0	10·5
Difference, being volatile solids,		5·0	3·5

2. *Determination of Chlorine.*

Chlorine may be determined very rapidly by the volumetric method. For this purpose a solution of potassium mono-chromate and a standard solution of silver nitrate are required.[1]

Take 100 c.c. of the water to be examined; place it in a glass vessel standing on a piece of white paper; add 1 c.c. of potassium mono-chromate solution, which must be free from chlorine, drop in the silver nitrate from the burette, and stir after each addition. The red silver chromate which is at first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. Neither the solution of silver nor the water must be acid; if the latter is acid it should be neutralised with a little precipitated carbonate of calcium. The number of c.c. of silver solution used gives exactly the parts of chlorine per 100,000 of water. To bring to grains per gallon, multiply by 0·7.

Example.—In 100 c.c. of water, 1 c.c. of potassium mono-chromate, and 1·5 c.c. of silver solution give a permanent red tint, therefore the water contains 1·5 parts per 100,000 of chlorine; $1{\cdot}5 \times 0{\cdot}7 = 1{\cdot}05$ grains per gallon.

3. *Hardness.*

Clark's very useful soap test offers a ready mode of determining this in a manner quite sufficient for hygienic and economic purposes. The processes with the soap test may be divided into two headings.

I. The determination of the aggregate earthy salts, and free carbonic acid, as expressed by the term *total hardness.* The aggregate determination can be divided into two kinds of hardness, viz., that which is unaffected and that which is affected by boiling, and these are termed the *permanent* and the *removable hardness.*

II. The determination of the amount of certain constituents, as the lime, magnesia, sulphuric acid, and free carbonic acid. These results are only approximative, especially in the case of the magnesia; but they are very useful, as they give us enough information for hygienic purposes, and are done in a very short time.

Apparatus and reagent required for the Soap Test.—Burette divided into tenths of a cubic centimetre; measure of 50 c.c. or 100 c.c.; stoppered bottles of about 100 c.c. (4 ounces) capacity. Standard soap solution, 1 c.c. = 2·5 milligrammes of calcium carbonate.[2]

Rationale of the Process.—When an alkaline oleate is mixed with pure water, a lather is given almost immediately; but, if lime, magnesia, iron, baryta, alumina, or other substances of this kind be present, oleates of these bases are formed, and no lather is given until the earthy bases are thrown down. Free (but not combined) carbonic acid prevents the lather. The soap combines in equivalent proportions with these bases, so that if the soap solution be graduated by a solution of known strength of any kind, it will be of equivalent strength for corresponding solutions of other bases. There

[1] For the preparation of the solutions, see Appendix A.
[2] See Appendix A.

are, however, one or two points which render the method less certain. One of these is that, in the case of magnesia, there is a tendency to form double salts (Playfair and Campbell), so that the determination of magnesia is never so accurate as in the cases of lime or baryta. Carbonic acid appears to unite in equivalent proportions when it is passed through the soap solution; but if it be diffused in water, and then shaken up with the soap solution, two equivalents of the acid unite with one of soap.

To avoid the repetition of the term "tenth of a centimetre," it will be convenient to call each tenth of a centimetre *one measure*, and this precipitates 0·25 of a milligramme of calcium carbonate.[1]

Processes with the Soap Test.

(*a*) *Determination of the total Hardness of the Water.*—Take 50 c.c. of the water; put it in a small stoppered bottle, and add the soap solution from the burette, shaking it strongly after each addition until a thin uniform beady lather spreads over the whole surface without any break. If the lather is permanent for five minutes, the process is complete; if it breaks before that time, add a drop or two more of the solution, and so proceed until a lather be obtained that is permanent for five minutes.

Then read off the number of *measures* of soap solution used.

From the total number of *measures* (or *tenths* of a centimetre) used deduct 2, as that amount is necessary to give a lather with 50 c.c. of the purest water, and this deduction has to be made in all the processes. The soap solution which has been used indicates the hardness due to all the ingredients which can act on it; in most drinking waters these are only lime and magnesian salts and free carbonic acid.

The amount of this total hardness is, for convenience, usually expressed either in degrees of the metrical scale (= parts per 100,000) or in grains per gallon of calcium carbonate, each grain representing 1 degree of hardness on the scale proposed by Dr Clark. Of course it is understood that the hardness depends on various constituents, but is equivalent to so much calcium carbonate.

This is done as follows:—

Each 0·1 c.c., or, in other words, each *measure*, of our soap solution corresponds to 0·25 mgm. of calcium carbonate. Multiply this coefficient by the number of measures of soap solution used, and the result is the hardness of 50 c.c. of water expressed as calcium carbonate. Then, as we have acted on 50 c.c. only, multiply by 2 to give the parts per 100,000; or, more simply, divide the net measures of soap by 2.

Example.—A lather was given with 3·2 c.c., or 32 measures of the soap solution. $(32 - 2) \times 0·25 \times 2 = 30 \times 0·5 = 30 \div 2 = 15$ degrees of hardness on the metrical scale; $15 \times 0·7 = 10·5$ degrees on Clark's scale.

To convert metrical degrees into Clark's scale, multiply by 0·7; to convert Clark's scale into metrical degrees, divide by 0·7.

If the hardness of the water exceeds 40 measures of the soap solution, 25 c.c. of water only should be taken, and 25 c.c. of distilled water added.

The result must then be multiplied by 2.

(*b*) *The Permanent or Fixed Hardness.*—Boil a known quantity in a flask briskly for half an hour, and replace the loss by distilled water from time to time; allow it to cool down to 60° Fahr. (15°·5 C.) in the vessel, which should be corked, and determine hardness in 50 c.c. If distilled water is not procurable, then boil 200 c.c. down to 100; take half the re-

[1] A weaker solution is often used; see Appendix A.

mainder (= 100 of unboiled water) and determine hardness.[1] After deducting 2 measures, divide the number of measures by 2 for the hardness of 50 c.c., and calculate as usual.

By boiling, all carbonic acid is driven off; all calcium carbonate, except a small quantity, is thrown down; the calcium sulphate and chloride are not affected if the evaporation is not carried too far; the magnesium carbonate at first thrown down is redissolved as the water cools.

Example.—Before boiling, 32 measures, and after boiling, 13 measures, of the soap solution were used.

$$13 - 2\ (= 11) \div 2 = 5{\cdot}5 \text{ degrees of the metrical scale.}$$
$$5{\cdot}5 \times 0{\cdot}7 = 3{\cdot}85 \text{ degrees of Clark's scale.}$$

(*c*) *Removable Hardness.*—The difference between the total and the permanent hardness is the temporary or removable hardness, which in the example would be 15 - 5·5 = 9·5 degrees of the metrical scale, and 10·5 - 3·85 = 6·65 degrees of Clark's scale.

The amount of permanent hardness is very important, as it chiefly represents the most objectionable earthy salts—viz., calcium sulphate and chloride, and the magnesian salts. The greater the permanent hardness, the more objectionable is the water. The permanent hardness of a good water should not, if possible, be greater than about 5° of the metrical scale, equal to 3° or 4° of Clark's scale.

The determination, then, of

1. The *total* hardness,
2. The *permanent* or *fixed* hardness,
3. The *temporary* or *removable* hardness,

will enable us to speak positively as to the hygienic characters of a water, so far as earthy salts are concerned.[2]

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[1] If there is much fixed hardness this process is hardly available.

[2] *Determination of certain Constituents by Soap.*—In many cases the analysis must end with the above processes; but it may be desirable to carry it further, and to determine the amount of some ingredients; for example, lime, magnesia, sulphuric acid, carbonic acid.

An approximate estimate can be given of several of these ingredients by the soap test, which is sufficient for hygienic purposes; and any one who has learned to determine properly the hardness of a water will be able to carry on the process into finer details.

Lime by the Soap Test.—Messrs Boutron and Boudet have proposed, after determination of total hardness, to precipitate the lime by ammonium oxalate, and then to determine the hardness again. The difference will be owing to lime removed. The difficulty here is to add enough, and not too much, of ammonium oxalate, which itself in excess gives hardness.

The best way to perform this process is to have a perfectly concentrated clear solution of ammonium oxalate, and to add to 50 c.c. of water 1 drop for every 4 measures of soap solution used; then in other bottles, to add respectively 1, 2, and 3 drops more. Then determine hardness of all the bottles and select the result which gives the least hardness. In this way we can hit on the bottle which contains enough, but not too much ammonium oxalate. The water need not be filtered, but it should be allowed to stand at least for three or four hours, or, better still, twenty-four hours, before the hardness is taken.

Then multiply the difference between the total hardness and the hardness after the addition of the oxalate by the coefficient for lime; this is 0·14 of a milligramme, as each measure of the soap solution is equivalent to this amount of lime.

Example.—Total hardness, ...	32
After lime precipitated, ...	10
Difference, ...	22

22 measures $\times 0{\cdot}14 \times 2 = 6{\cdot}16$ parts of lime per 100,000 and $6{\cdot}16 \times 0{\cdot}7 = 4{\cdot}312$ grains per gallon. Or multiply the number of measures by 0·28, this gives parts per 100,000; or by 0·196, the result is grains per gallon. If carefully done, this result will be near the truth.

Magnesia by the Soap Test.—Boutron and Boudet propose to determine the magnesia by boiling the water from which the lime has been thrown down. All usual elements of hardness, except the magnesia, are thus got rid of. This is by no means so accurate a process as that of the lime; the lather is formed much less perfectly and sharply, and in addition the

4. *Determination of the Organic Matters and their Products in Water.*

As already stated, the determination of organic matter in water is difficult, and many processes have been proposed. Some are obviously out of the question for medical officers, save in exceptional circumstances. Those, therefore, are described here which are not only likely to give sufficient information for hygienic purposes, but also to be within the range, for the most part, of the medical officer's appliances.

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constitution of the magnesia and soap compound is variable. The result must be considered as quite approximative, but may sometimes be rendered more accurate by diluting with distilled water.

Take 200 c.c. of water; add to it the number of drops of solution of ammonium oxalate known to be sufficient by the lime experiment; allow to stand for twenty-four hours; filter, boil for half an hour, replace loss by distilled water; allow to cool in the vessel, which should be well corked, and determine hardness in 50 c.c.

As the lime has been thrown down and the carbonic acid driven off, the hardness is owing to magnesian salts of some kind.

Calculate as magnesia, the coefficient of which, for each measure of soap solution, is 0·1, or, as magnesium, the coefficient of which is 0·06.

Example.—Hardness, after driving off carbonic acid by boiling and precipitating lime = 7

$(7-2) \times 0{\cdot}1 + 2 = 1{\cdot}0$ part of magnesia per 100,000; $1{\cdot}0 \times 0{\cdot}7 = 0{\cdot}7$ grain per gallon.

Or multiply the number of measures corrected for lather by 0·2, the result is parts per 100,000: or by 0·14; the result is grains per gallon.

Although this result is approximative, it is really nearer the truth than the determination by weighing in the hands of a beginner.

Free Carbonic Acid by the Soap Test.—In order to get rid of the fallacy from free carbonic acid acting on the soap, Clark recommended that the water should be well shaken in a bottle, so as to disengage some of the CO_2, and then that the air should be sucked out. But this does not entirely remove the carbonic acid.

By the soap test the free carbonic acid can be determined in the following way:—Throw down all the lime carefully by ammonium oxalate, without adding an excess, and determine the hardness in 50 c.c. as usual. The hardness will be owing to magnesian salts and carbonic acid. If now the water, freed from lime, be boiled, and the loss of water replaced by distilled water, the carbonic acid will be driven off. The hardness should be then again determined. The difference between the first and second trials will give the amount of soap solution which had been previously acted on by the carbonic acid.

Example.—1. Total magnesian and carbonic-acid hardness,	=	12 measures.
2. Magnesian hardness, ...	=	7 ,,
Carbonic-acid hardness, . . .	=	5 ,,

1 measure of soap sol. corresponds to 0·22 milligrammes carbonic acid. Therefore,

$0{\cdot}22 \times 5 \times 2 = 2{\cdot}2$ = centigrammes per litre, or parts, by weight, in 100,000,
and $2{\cdot}2 \times 0{\cdot}7 = 1{\cdot}54$ grains per gallon.

But gases are usually stated in volume, either c.c. per litre or cubic inches per gallon. Now 1 centigramme = 5·06 c.c., therefore $2{\cdot}2 \times 5{\cdot}06 = 11{\cdot}132$ c.c. per litre; or multiply the *net* measures of soap by 2·23; $5 \times 2{\cdot}23 = 11{\cdot}15$, which is sufficiently near. To bring to cubic inches per gallon multiply the grains by 2, thus: $1{\cdot}54 \times 2 = 3{\cdot}08$ cubic inches, since 2 cubic inches weigh 1 grain at 32° F. and 30 in. barometer, or multiply the *net* measures of soap by 0·616; thus: $5 \times 0{\cdot}616 = 3{\cdot}08$ cubic inches. To convert c.c. per litre into cubic inches per gallon, divide by 3·61; thus: $11{\cdot}132 \div 3{\cdot}61 = 3{\cdot}08$.

Determination of Lime and Magnesia by Weight.

It may be desired to determine the lime and magnesia by weight, and the following processes can then be used:—

Lime by Weight.—Take a known quantity of water; add ammonium oxalate, and then ammonia enough to give an ammoniacal smell. Allow precipitate thoroughly to subside, and then wash by decantation, or by throwing the precipitate on a small filter of Swedish paper, the weight of the ash of which is known. Decantation is recommended. If a filter is used, wash precipitate on filter; dry; scrape precipitate from filter, and place in a platinum crucible; burn filter to an ash, by holding it in a strong gas flame, and place it also in the crucible. Heat the crucible to gentle redness for fifteen minutes, moisten with a little water, and test with turmeric paper. If no reaction is given, the process is done. If the paper is browned (showing presence of caustic lime), recarbonate with ammonium carbonate, drive off excess of ammonia, dry, and weigh.

The substance weighed is calcium carbonate; multiply by 0·56, and the result is lime; or by 0·40 for calcium alone.

The analysis may be considered under two heads—

(A) The determination of *nitrogenous organic matters* and their products.

(B) The determination of *oxidisable organic matter*, probably chiefly *non-nitrogenous.*

(A) Includes—

(*a*) The determination of the *free, saline,* or *combined ammonia.*

(*b*) ,, of the (so-called) *albuminoid ammonia.*

(*c*) ,, of the *nitric acid, existing as nitrates.*

(*d*) ,, of the *nitrous acid, existing as nitrites.*

(B) Includes—

(*e*) The determination of the *oxidisable organic matter* by the permanganate processes.

(A) *Determination of the Nitrogenous Organic Matters and their Products.*

Determination of the Free and Albuminoid Ammonia.—For this analysis we require [1]—1. A standard solution of ammonium chloride, 1 c.c. of which $=0·01$ of a milligramme of ammonia (NH_3); 2. Nessler's solution as a reagent for the detection of ammonia; 3. A solution of potassium permanganate and caustic potash; 4. Pure distilled water.

(*a*) *Free Ammonia.*

Place in a retort 250 c.c. of the water to be examined. Attach the retort to a Liebig's condenser, and distil off about 130 c.c.; collect 1 c.c.

Mohr's plan might also be used, viz., precipitation of the lime in an ammoniacal solution by standard oxalic acid, and then titration of the excess of the latter by permanganate.

Magnesia by Weight.—Take the water from which the lime has been thrown down; evaporate to a small bulk; filter if there be turbidity; add solution of ammonium chloride, and ammonia to slight excess; then add a solution of sodium phosphate; stir with a glass rod; set aside for twelve hours; throw precipitate on a filter, carefully detaching it from the sides of the glass; wash with ammoniacal water; dry; incinerate in an intense heat; weigh, taking care to deduct the ash of the filter known by previous experiment. The substance is magnesium pyrophosphate; multiply by 0·36036 to get the amount of magnesia, or by 0·21622 for magnesium alone.

Sulphuric Acid by Weight.—Take a known quantity of the water (500 to 1000 c.c.), acidify with hydrochloric acid and evaporate, but not so far as to run any risk of throwing down sulphate of calcium; filter; and then add chloride of barium; allow to stand, and wash the precipitate by decantation; dry; weigh; multiply precipitate by 0·34335 to get the amount of sulphuric anhydride (SO_3) or by 0·412, if it is wished to calculate it as SO_4.

Sulphuric Acid by Soap Test.—This plan was proposed by Boutron and Boudet, and is briefly as follows:—The hardness of the water being known, 50 c.c. of the standard barytic solution (0·26 grammes per litre) are added to 50 c.c. of water, and the mixture is allowed to stand for twenty-four hours. The hardness (supposing no SO_4 were present) would be exactly equal to the original hardness of the water and of the barytic solution combined. But SO_4 being present, barium sulphate is precipitated, and there is a loss of hardness. Each degree of loss equals 0·24 mgm. of sulphur tetroxide (SO_4).

Example.—Original hardness, ...	32
50 c.c. barytic solution, ...	22
	54
After precipitation, ...	45
Difference, ...	9

$0·24 \times 9 \times 2 = 4·32$ parts per 100,000; $4·32 \times 0·7 = 3·02$ grains per gallon.

Usually the process gives good results. Occasionally, from some cause which is not clear, the barium sulphate does not precipitate. This does not depend on the amount of sulphuric acid. The ease with which this process is done renders it useful. The barytic solution is only strong enough to precipitate 6·72 grains of sulphuric acid (SO_4) per gallon, so that half the water only must be taken, or less, if the sulphuric acid be evidently in large amount.

Short factors: for $SO_3=0·280$, for $SO_4=0·336$ to state as grains per gallon; for $SO_3=0·40$, for $SO_4=0·48$ to state as parts per 100,000.

[1] For these solutions, see Appendix A.

more of the distillate, and test it with a few drops of Nessler, to see if any ammonia is still coming over; if so, the distillation may be continued longer. Carefully measure the amount of distillate; test a little with Nessler's solution in a test-tube; and, if the colour be not too dark, take 100 c.c. of the distillate and put it into a cylindrical glass vessel, placed upon a piece of white paper. Add to it $1\frac{1}{2}$ c.c. of Nessler. Pour into another similar cylinder as many c.c. of the standard ammonium chloride solution as may be thought necessary (practice soon shows the amount), and fill up to 100 c.c. with pure distilled water; drop in $1\frac{1}{2}$ c.c. of Nessler. If the colours correspond up to three to five minutes, the process is finished, and the amount of ammonium chloride used is read off. If the colours are not the same, add a little more ammonium chloride so long as no haze shows itself; if it does, then a fresh glass must be taken, and another trial made. When the process is completed, read off the number of c.c. of ammonium chloride used, allow for the portion of distillate not used, multiply by 0·01 and then by 0·4: the result is centigrammes of free ammonia per litre, or parts per 100,000; multiply the latter by 0·7 to bring to grains per gallon, if required.

Example.—From 250 c.c. of water 133 were distilled; 100 c.c. were taken for the experiment; 4·5 c.c. of ammonium chloride solution were required to give the proper colour; then $4{\cdot}5 \times \frac{133}{100} \times 0{\cdot}01 \times 0{\cdot}4 = 0{\cdot}02394$ per 100,000 of free ammonia.

Should the colour of the distillate prove too dark, a smaller quantity may be used, and made up to 100 c.c. with distilled water. Wanklyn recommends distilling only 50 c.c., Nesslerising it, and then adding one-third to the result, on the ground that (as he says) three-fourths of the ammonia come off in the first 50 c.c. He also states that with smaller sized apparatus 100 c.c. of water gives satisfactory results.[1] The Society of Public Analysts recommend successive portions being distilled over, and Nesslerised until ammonia ceases to appear. Practically we have found at Netley that the whole of the ammonia comes over in the first 130 c.c., or nearly so.

The use of permanent coloured solutions, corresponding with known amounts of ammonia, has been recommended, and caramel has been tried at Netley, but the results have not been very satisfactory. A colorimeter may be used if preferred.

When a Liebig's condenser cannot be obtained, a flask may be used instead of a retort, and the distillate conveyed to the receiver by a tube of glass (or block tin) passing through a vessel of cold water, which must be renewed from time to time. The tube may be bent in any convenient way, so as to expose it to the cooling water as much as possible. Every part of the apparatus must be scrupulously clean and well washed with distilled water previous to commencing the experiment. The S.P.A. recommend that the retort tube should be packed into the condensing tube by means of an india-rubber ring; or it may be done with clean writing-paper, as Wanklyn proposes. In either case the substance used must be quite clean. It is well to wash the retort, flask, and glass tubes with dilute sulphuric acid, and then rinse them out clean with distilled water. In distilling, the retort should be thrust well into the flame, and the distillation carried on rapidly. If the water is very soft, the addition of a little pure or recently heated sodium carbonate may be made, but in ordinary circumstances it is not necessary, and is not advisable.

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[1] *Water Analysis*, 5th edition, p. 41.

The "free" or "saline ammonia" represents the ammonia combined with carbonic, nitric, or other acids, and also what may be derived from urea, or other easily decomposable substances, if they are present. The limit in good waters is taken at 0·002 centigrammes per litre; in bad waters it often reaches 100 times this and more.[1]

After the distillation of the free ammonia, the residue of the water in the retort is used for determining the *albuminoid ammonia*, to be now described.

(*b*) *Albuminoid Ammonia.*

The object of this process is to get a measure of the nitrogenous organic matter in water, by breaking it up and converting the nitrogen into ammonia by means of potassium permanganate in presence of an alkali; the ammonia can be distilled off and estimated as above. It is to be understood that this does not deal with all the nitrogenous matter, but the results are sufficiently uniform to be useful. According to Wanklyn and Chapman, the albuminoid ammonia multiplied by 10 gives a fair approximate estimate of the nitrogenous matter in water.

Process.—25 c.c. of the solution of alkaline permanganate[2] are added to the residue in the retort, after the distillation of the free ammonia, and about 110 to 120 c.c. distilled off. It is sometimes convenient to add a little pure distilled water to the residue if the first distillation has been carried rather far. Wanklyn recommends successive quantities of 50 c.c. to be distilled off and tested until no more ammonia comes over. Determine the amount of ammonia, as was done in the case of the free ammonia, and state the results in this case as *albuminoid ammonia*. In this distillation there is sometimes a little difficulty caused by "bumping," especially in the case of bad waters; to remedy this it has been recommended to use pieces of tobacco pipe which have been heated to redness immediately before use. It is better, however, to dilute the water if it be a bad one, and not to distil too rapidly.

(*c*) *Nitric Acid.*

Nitric acid may be determined in several ways, but two seem more easily applicable than the others, viz., 1, Schulze's aluminum method (modified by Wanklyn and Chapman); and 2, the copper-zinc process. Both methods depend upon the conversion of the nitric acid into ammonia.

1. *Aluminum Process.*—We require solution of caustic soda, perfectly free from nitrates, and aluminum foil.[3] 100 c.c. of the water (50 c.c., S.P.A.) are mixed with an equal bulk of the soda solution, and put into a retort, and a piece of aluminum foil, larger than is capable of dissolving, added. The tube is well corked, and the mixture left for several hours. The liquid is then distilled and Nesslerised; or, if the quantity of ammonia be very large, it may be determined with a standard acid solution. Precautions are suggested for the prevention of the escape of ammonia or the access of ammonia from the air, but with a good cork they are hardly required.

2. *Copper-zinc Process.*—A wet[4] copper-zinc couple is prepared, and well washed with distilled water, and afterwards with some of the water to be

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[1] Wanklyn's *Water Analysis*, 5th edition, p. 48.

[2] See Appendix A.

[3] See Appendix A.

[4] In Frankland's *Water Analysis*, p. 100, the directions given are for a *dry* couple, which appears to be an error. See M. W. Williams, *Analyst*, vol. vi. p. 36. For preparation, see Appendix A.

examined. To use it, put it into a wide-mouthed stoppered bottle, and pour in 100 c.c. of the water to be examined; it is best to fill the bottle up, and to add 1 per 1000 of sodium chloride, especially if the water be very soft. The stopper is inserted, and the whole put aside for several hours,—ten or twelve if the temperature be below 30° C. (86° Fahr.); but the process may be hastened by warming up to 32° to 38° C. (90° to 100° Fahr.). The completion of the process may be ascertained by the absence of *nitrous acid*, when tested for by Griess's test. The water is now to be Nesslerised, which can rarely be done properly except after distillation, as in the former process.

The calculation is made by calculating out the resulting ammonia as nitrogen or as nitric acid,—the following being the coefficients:—

$$1 \text{ part of } NH_3 = 3{\cdot}706 \text{ of nitric acid, } HNO_3; = 3{\cdot}647 \text{ of } NO_3;$$
$$= 3{\cdot}176 \text{ of nitrogen pentoxide, } N_2O_5; = 0{\cdot}8235 \text{ nitrogen, } N.$$

It is necessary to take into account any nitrous acid or ammonia (free or saline) which may be present, and may have been previously determined. Nitrous acid (HNO_2) is to ammonia (NH_3) as 2·765 to 1; or, if nitrogen tetroxide be taken (NO_2), then it is to ammonia (NH_3) as 2·706 to 1.

Example.—100 c.c. of water yielded 0·03371 centigrammes of NH_3 (equal to 0·3371 parts per 100,000) after treatment by either of the above processes for the reduction of nitrates. But the sample had also yielded 0·0052 of free ammonia, and 0·127 of nitrous acid, reckoned as NO_2; the latter, 0·127, divided by 2·706, being equivalent to 0·0469 of NH_3; we therefore have

$$0{\cdot}3371 - (0{\cdot}0052 + 0{\cdot}0469) = 0{\cdot}285 \text{ ammonia from nitric acid.}$$

$$0{\cdot}285 \times 3{\cdot}706 = 1{\cdot}0562\ HNO_3. \quad\Big|\quad 0{\cdot}285 \times 3{\cdot}176 = 0{\cdot}9052\ N_2O_5.$$
$$0{\cdot}285 \times 3{\cdot}647 = 1{\cdot}0394\ NO_3. \quad\Big|\quad 0{\cdot}285 \times 0{\cdot}8235 = 0{\cdot}2347\ N.$$

Multiplying these results by 0·7, we have grains per gallon. The statement of the result as *nitrogen* is now becoming very general.

(*d*) *Nitrous Acid.*

For the direct determination of this the plan of Griess is now recommended. A solution of meta-phenylenediamine is prepared, and also a dilute sulphuric acid, consisting of one volume of strong acid to two of water. One c.c. of each solution is added to 100 c.c. of the water to be examined, which is put in a Nessler glass: a red colour is produced. Another glass is placed alongside, and into it are put as much of a standard solution of potassium nitrite as may be necessary, making up the bulk to 100 c.c. with distilled water; then add 1 c.c. each of the sulphuric acid and the meta-phenylenediamine. The remainder of the process is carried on much in the same way as ordinary Nesslerising for ammonia. Care must be taken that the water originally taken is not too strong; so if the red colour be too deep, smaller portions diluted up to 100 c.c. must be taken, until the faintest tint distinctly recognisable is obtained. The standard potassium nitrite [1] should be of the strength of 1 c.c. = 0·01 milligramme of NO_2, or nitrogen tetroxide. The number of c.c. used gives the milligrammes of NO_2 present in the sample of water.

Example.—A sample of water containing a good deal of nitrous acid was taken, and 25 c.c., made up to 100 c.c. with pure distilled water, were put in a Nessler glass. 1 c.c. of the sulphuric acid and 1 c.c. of the solution

[1] For the preparation of the solutions, see Appendix A.

of meta-phenylenediamine added: a distinct red colour was obtained. Into another Nessler glass 7·5 c.c. of the standard potassium nitrite were put, made up to 100 c.c. with distilled water, and the same shade of tint obtained with the solution as above.

$$\begin{aligned} & \qquad\quad \text{Mgm.} \\ 7{\cdot}5 \times 0{\cdot}01 &= 0{\cdot}075\ NO_2 \text{ in 25 c.c.} \\ 0{\cdot}075 \times 4 &= 0{\cdot}300\ NO_2 \text{ in 100 c.c.} \end{aligned}$$

This equals 0·3 in 100,000 or 0·21 in 1 gallon; multiplying any of these results by 0·304, gives the amount of nitrogen (N).

The above is now accepted as the most accurate method of determining nitrites,[1] but some care is required,—for both the water and the colouring solution must be either colourless or be decolorised. It may not be always possible to get the reagents, and then it is best to fall back upon the determination of nitrous acid by the permanganate process to be presently described.

It may be well to mention here that the method of stating the results varies, as in the case of nitric acid, some reckoning as HNO_2, some as N_2O_3, and others as NO_2. The last is the best, as it corresponds to Cl. In the same way NO_3 is to be preferred for the nitric acid, SO_4 for the sulphuric acid, and PO_4 for the phosphoric acid.

(B) *Determination of Oxidisable Matter in Water.*

The oxidisable matter in water consists of oxidisable organic matter, nitrites, ferrous salts, and hydrogen sulphide. The last can be easily recognised by the smell, and got rid of by gently warming the water. Ferrous salts are rare, but, if present, they impart a distinct chalybeate taste to the water if their amount reaches the fifth of a grain of iron per gallon (about 0·3 parts per 100,000). Generally their presence may be disregarded. There remain, therefore, the oxidisable organic matter, and nitrous acid as nitrites. For determining these the potassium permanganate is very convenient.

(e_1) *Total Oxidisable Matter in terms of Oxygen required for its Oxidation.*—A solution of potassium permanganate is required, which in presence of an acid is capable of yielding 0·01 centigramme of oxygen for each c.c.

Process.—Take a convenient quantity of the water to be examined, say 250 c.c.; add 3 c.c. of sulphuric acid; drop in the permanganate solution from a burette until a pink colour is established; warm the water up to 140° Fahr. (60° C.), dropping in more permanganate if the colour disappears; when the temperature reaches 140° Fahr. remove the lamp; continue to drop in permanganate until the colour is permanent for about ten minutes. Then read off the number of c.c. used, and multiply by 0·04 to get the amount per 100,000.

Example.—250 c.c. of water, with 3 c.c. of sulphuric acid, required 3·5 c.c. of permanganate to give a permanent colour; $3{\cdot}5 \times 0{\cdot}4 = 0{\cdot}04 = 0{\cdot}14$ per 100,000.[2]

It must be remembered that this includes both organic matter and nitrous acid. We must now differentiate these.

(e_2) *Organic Oxidisable Matter in terms of Oxygen required for its Oxida-*

[1] See Frankland, *Water Analysis*, p. 40, also M. W. Williams, in *Analyst*, vol. vi. p. 36.

[2] If special accuracy is required, a correction for colour may be made by deducting 0·06 from the result stated as milligrammes of oxygen per litre.

tion.—Take 250 c.c. of water to be examined; add 3 c.c. of sulphuric acid as above; boil the water briskly for twenty minutes; allow it to cool down to 140° Fahr. (60° C.); then add the permanganate until a pink colour is established for ten minutes. Calculate out the oxygen as above, stating the result as centigrammes per litre required for oxidisable organic matter, or, shortly, as *organic oxygen.*

(e_3) *Nitrous Acid.*—This can now be determined easily by calculating from the difference between the two preceding processes. Each centigramme of oxygen represents 2·875 centigrammes of nitrous acid; we must therefore multiply the difference by this factor, and the result is nitrous acid in centigrammes per litre.

Example.—A sample of water yielded, by process (e_1), 0·14 parts of oxygen per 100,000; by process (e_2), 0·075. Then we have $0·140 - 0·075 = 0·065$ = centigrammes of oxygen required for nitrous acid; $0·065 \times 2·875 = 0·187$ per 100,000 of nitrogen tetroxide (NO_2).

Hassall[1] has suggested an improvement on the above process (de Chaumont's), namely, instead of boiling away the nitrous acid, to distil it over and determine it directly in the distillate. Fresenius proposes a somewhat similar plan, only using acetic acid for the distillation, and then sulphuric acid for the subsequent titration. Of course, if distillation is resorted to, the NO_2 can be determined by Griess's method.

One or two precautions are necessary in the permanganate processes. In process (e_1) permanganate must be added to the water from the very commencement, in order not to lose nitrous acid, which may be driven off as the water is being heated. The faintest tinge of colour that can be distinctly seen ought to be accepted, provided it remain for ten minutes. Care must be taken to add the sulphuric acid in every case at the beginning; if this is not done a brown colour is struck which spoils the experiment. Sometimes this colour appears, even after acid is added, and is then probably due to excess of organic matter; dilution with distilled water sometimes remedies this. The permanganate solution always acts upon the india-rubber tube of the common burette, therefore it is always well to use a burette with a glass stop-cock, or to run off the portion which has been in contact with the india-rubber before beginning the experiment.

The S.P.A. instructions recommend another method of operation (suggested by Tidy) including two determinations, viz., one in which the oxygen absorbed within fifteen minutes is calculated, and another within four hours. The processes are carried on at a temperature of 80° Fahr. (26°·7 C.). Two bottles, stoppered and of about 12 oz. (340 c.c.) capacity, are used, into each (after being thoroughly cleaned, rinsed with sulphuric acid and then with the water to be examined) 250 c.c. of the water are to be put, and warmed in a bath to 80° Fahr. (26°·7 C.). Then add 10 c.c. of dilute sulphuric acid (1 vol. to 3 vols. of water) and 10 c.c. of the standard potassium permanganate solution. Fifteen minutes after the addition of the potassium permanganate one of the bottles must be removed from the bath, and two or three drops of the potassium iodide solution added, to remove the pink colour. After thorough mixture, run from a burette the standard solution of sodium hyposulphite, until the yellow colour is nearly destroyed, then add a few drops of starch water, and continue the addition of the hyposulphite until the blue colour is discharged. If the titration has been properly conducted, the addition of one drop of potassium permanganate

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[1] *Adulterations Detected*, 1876, p. 84.

solution will restore the blue colour. At the end of four hours remove the other bottle, and titrate as above described. Should the pink colour of the water in the bottle diminish rapidly during the four hours, further measured quantities of the standard solution of potassium permanganate must be added from time to time, so as to keep it markedly pink.

The hyposulphite solution must be *standardised* by making a blank experiment with distilled water, and this must be repeated from time to time as it does not keep well. Let A be the quantity of hyposulphite required in the blank experiment, and let B be the amount required for 250 c.c. of the water examined, and a the amount of permanganate solution used,

$$\left(1 - \frac{B}{A}\right) \times a \times 0{\cdot}04 = \text{oxygen absorbed per 100,000 parts.}$$

Example.—To 250 c.c. of water 10 c.c. of permanganate solution were added: in the previous blank experiment 10 c.c. of permanganate took 45 c.c. of the hyposulphite: after mixture with the water and the lapse of the necessary time, 30 c.c. of hyposulphite were required: then,

$$\left(1 - \frac{30}{45}\right) \times 10 \times 0{\cdot}04 = 0{\cdot}13\dot{3} \text{ oxygen per 100,000 parts.}$$

The factor 0·04 is got by multiplying by 0·01 (=the centigrammes of oxygen in 1 c.c. of the permanganate solution) and then by 4 to bring to 100,000. Should the 250 c.c. require more than 10 of permanganate, the value of a will alter accordingly.

It is of course to be understood that the nitrous acid, if present, must be allowed for, and other oxidisable substances eliminated before the oxygen for organic matter is definitively recorded.

The permanganate process is the only one that is practicable for medical officers, that gives us any measure of the oxidisable organic matter in water, and is, in the present state of our knowledge, indispensable, imperfect though its indication may be. It is certainly an aid to our judgment of the condition of a drinking water, being to Frankland's carbon process something the same as the albuminoid ammonia method is to his nitrogen one. Frankland has fully acknowledged this relation in his latest work,[1] and has proposed a series of factors by which to multiply the oxygen absorbed, so as to express the result in terms of organic carbon. These factors are based on the observed relations between the two processes in a very large number of experiments, and are formed by dividing the average carbon by the average oxygen. The factors differ for different kinds of water in the following proportions:—

River water,	$\frac{C}{O}$	=	2·38
Deep-well water,	,,	=	5·80
Shallow-well water,	,,	=	2·28
Upland surface water,	,,	=	1·80

so that 1 centigramme of oxygen absorbed indicates a probable amount of only 1·8 of organic carbon in an upland surface water, but as much as 5·8 in a deep-well water.

No process gives us thoroughly trustworthy information, but for the army or navy medical officer, or any one not provided with a well-appointed laboratory, the permanganate process, combined with the albuminoid ammonia

[1] *Water Analysis*, 1880, p. 55.

process, gives as much information as is likely to be got at present, and sufficient for hygienic purposes. It must be remembered that the permanganate does not act upon fatty substances, starch, urea, hippuric acid, creatin, sugar, or gelatine.

Action of Permanganate in presence of an Alkali.

In order to avoid some of the fallacies and inconveniences of the test with acid, F. Schultze[1] tried the following plan, which was slightly modified by Lex. Five or more vessels, each containing 60 c.c. of the water to be examined, are taken, and to each 2 c.c. of thin milk of lime are added, and then 1, 2, 3, 4, 5 c.c. &c. of the permanganate solution (viz., ·395 gramme per litre) are added, and left for three hours. At the end of that time some of the samples will be decolorised, others still coloured; if No. 1 and No. 2 are colourless, and No. 3 is coloured, then the amount of permanganate destroyed is between 2 and 3 c.c. As in the cold each equivalent of permanganate only gives off 3 (not 5 atoms) of oxygen, each c.c. corresponds not to 0·01, but to 0·006 centigramme of oxygen.[2] It is for this reason that 60 c.c. of water are taken instead of 100, for it is evident that if 1 c.c. of the permanganate solution gives only 0·006 centigramme to 60 c.c., it is the same as 0·01 to 100 c.c. of the water. The calculation of the result is thus easy; if, for example, Nos. 1 and 2 are decolorised, while No. 3 is coloured, the amount of oxygen required is between 0·02 and 0·03 centigramme for 100 c.c., or 0·2 and 0·3 parts per 100,000. If 60 c.c. of a water take less than 3 c.c. of the permanganate solution to give it a colour permanent for two hours, it is a good water (according to Lex) so far as this test is concerned; if 3 and 4 c.c. are required it is a medium water, and if the 5 c.c. do not give a colour the water is bad.

5. *Phosphoric Acid in Phosphates.*

The incinerated total residue of the solids is to be treated with a few drops of nitric acid, and the silica rendered insoluble by evaporation to dryness. The residue is then taken up with a few drops of dilute nitric acid, some water is added, and the solution is filtered through a filter previously washed with dilute nitric acid. The filtrate, which should measure 3 c.c., is mixed with 3 c.c. of molybdate solution, gently warmed, and set aside for fifteen minutes at a temperature of 80° Fahr. The result is reported as "traces," "heavy traces," or "very heavy traces," when a colour, turbidity, or definite precipitate are respectively produced, after standing fifteen minutes. The precipitate may also be collected and weighed, if thought desirable. For this purpose it ought to be washed with the least quantity of distilled water, and then dissolved to neutrality in dilute ammonia. The solution thus obtained is evaporated with repeated additions of small quantities of water, and the resulting residue is weighed. The weight, divided by 28·6, gives the amount of phosphoric anhydride, P_2O_5 (Hehner). To express it in terms of PO_4, divide by 21·4, or multiply by 0·0467.

6. The determination of *sulphuric acid* has already been referred to (page 691, note).

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[1] Roth and Lex, *op. cit.*, p. 91.

[2] With sulphuric acid the following is the reaction:—

$$2(KMnO_4)+3(H_2SO_4)=K_2SO_4+2(MnSO_4)+3(H_2O)+O_5\,;$$

without acid the reaction is:

$$2(KMnO_4)+H_2O=2(MnO_2)+2(KHO)+O_3.$$

Determination of the Earthy and Alkaline Carbonates by Mohr's Process.

This is a very elegant process, and may be useful. The solutions required are: standard solution of sulphuric acid,[1] 1 c.c. of which saturates 5 mgms. of calcium carbonate; and a colouring solution, such as cochineal or phenolphthaleine.

Process.—Take 100 c.c. of the water to examine, and add a drop or two of cochineal solution, which gives a carmine-red colour. Then run in the standard acid solution till the colour becomes yellow or brown-yellow. Read off the number of c.c. used, and multiply by 5. The result is parts of earthy and alkaline carbonates per 100,000, stated as calcium carbonate.

Example.—100 c.c. of a sample of water, reddened with cochineal, required 5·6 of standard solution to make it yellow:—then $5 \cdot 6 \times 5 = 28$ = parts per 100,000 of earthy and alkaline carbonates as calcium carbonate. If the water be not alkaline to test-paper, the result will represent calcium carbonate only. Should the latter be already known (through the hardness), the difference, if any, will represent sodium carbonate, and may be calculated out as such, 1 c.c. = 5·3 mgms. of sodium carbonate.

Iron, Silica, Lead, Copper, Arsenic, Zinc.

Iron is seldom required to be determined quantitatively, but it may be done by a colorimetric test (as suggested by Wanklyn). Either the water may be tested directly, or, what is better, the incinerated residue of the solids may be treated with pure hydrochloric acid, and made up to 100 c.c. with distilled water. A cubic centimeter of solution of ferrocyanide of potassium is added, which will strike a blue colour. A comparative experiment with a standard solution of iron may be made.[2] This is a better process than the permanganate method, which with small quantities of iron gives very uncertain results.

Silica may be determined from the incinerated residue, by treating it with strong nitric or hydrochloric acid, evaporating to dryness, and again treating with acid; distilled water (about 50 c.c.) is then added, and a little heat applied till everything soluble is dissolved; the residue is silica, which may be collected on a small filter, ignited, and weighed. A number of Indian waters contain considerable quantities of silica, either combined or in the suspended matter.[3]

Lead, Copper, Arsenic, Zinc.—The mere presence of these metals in appreciable quantity is enough to condemn a water, therefore it will seldom be necessary to determine their amount quantitatively.

Inferences from the Quantitative Tests.

The conclusions to be drawn from the qualitative tests hold good for the quantitative, only greater precision is given. It must, however, be understood that such conclusions are still only approximative, and they are only of a certain value when all the circumstances of the case are taken into consideration. Some chemists have gone so far as to say that they would

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[1] See Appendix A.
[2] See under *Alum in Bread.*
[3] Dr Nicholson, A.M.D., noticed that the water at Kampti, both from the river and from wells, contains from 2 to 6 grains per gallon (=3 to 9 parts per 100,000) of silica derived from micaceous gravel; it is combined with magnesia, and it renders the soap test inapplicable.

rather know nothing about the sample, and merely wish it marked with some distinctive mark, such as A or B, or 1 or 2, their confidence being so great in the indications of their analyses that they feel convinced they can give a perfectly trustworthy opinion on the wholesomeness or otherwise from these alone. There is no doubt that a practised chemist may make a fairly good *guess* under such circumstances, but as a rule an opinion so formed is worth very little. It is, of course, desirable that an analyst should come to his inquiry perfectly unbiassed; but before adopting a conclusion as regards a water, the medical officer will always do well to obtain every item of information about it that it is possible to get,—otherwise he is sure to fall sooner or later into error. Thus, constituents may be present in a deep-well water and have no particular significance, whilst in a shallow-well water they would be sufficient to condemn it. At present we have little or no means of positively distinguishing vegetable from animal organic matter; yet it is obvious that an amount of the former would be admissible which could not be allowed of the latter.

The inadvisability of drawing hard and fast lines on the subject is being now more generally recognised; and the remark of Mr Charles Ekin[1] is very apposite, for he says it is as if *six* typhoid germs were harmless and *nine* were hurtful. It may be true that the larger the dose of poison the more certain the effect, but we know too little at present to allow us to say where the line is to be drawn. At the same time, some approximation to classification may be made. The Reports on Hygiene in the *A.M.D. Annual Reports*, vols. xviii. to xxi., may be referred to for tables of water analyses, with approximate classifications.

Subjoined, in pp. 703–6, are tables of typical waters divided into four classes,—1. Pure and wholesome; 2. Usable; 3. Suspicious; and 4. Impure. These are merely suggested as general guides, some latitude being necessary, according to circumstances.

1. *Chlorine in Chlorides.*—The purest waters contain small quantities of chlorides, generally less than 1·5 per 100,000. Rain-water generally contains 0·22 to 0·5 per 100,000. An increase in ordinary drinking water may be due to sea-water, salt-bearing strata, or sewage, or other impurities. In the two former cases it is comparatively innocent, but in the last it may be an indication of dangerous contamination, in which case it is usually connected with an increase in the ammonias, the oxidisable matter, and the nitrogen acids. Sewage contamination can never take place without some increase in the chlorides, unless it be through gaseous emanations. Some deep wells contain large quantities of chlorides, but the other details of the analysis will show that this is not due to any recent contamination. Generally speaking, however, an excess of chlorine is a reason for suspicion, until a satisfactory explanation of its presence is obtained.[2]

2. *Solids, Total and Volatile.*—The amount of solids varies very greatly with the source of the water. Pure upland surface waters contain very little, sometimes not more than 3 to 4 parts per 100,000. The Loch Katrine water, supplied to Glasgow, yields only 2·4 per 100,000; Thirlmere Lake, proposed as the supply for Manchester, about the same; and Vyrnwy, proposed as the supply for Liverpool, 3·4 per 100,000.

On the other hand, waters from pure sources other than upland surface show much more than this. On the whole, we may lay it down that the

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[1] *Potable Water*, by Charles Ekin, F.C.S. J. & A. Churchill.

[2] Good deep-well water may contain 10 grains of chlorine per gallon: sewage effluent (as at Aldershot) only 2·8.

purest upland surface waters seldom contain more than about 7 parts per 100,000, but that considerable latitude may be admitted in waters from deep wells, chalk strata, and the like.

Of the solids not more than about 1·5 per 100,000 ought to be volatile, or capable of being driven off by a red heat. The solids should blacken very slightly on ignition. A little deviation from this rule is admissible in water from peat land.

3. *Ammonia, Free and Albuminoid.*—Pure waters yield from *nil* to 0·002 per 100,000 of free ammonia, and from *nil* to 0·005 per 100,000 of albuminoid ammonia. Usable water may contain up to 0·005 per 100,000 of free, and 0·01 per 100,000 of albuminoid ammonia. These numbers, however, require qualification, for they may be exceeded in cases where water is thoroughly good for dietetic purposes. Rain-water often contains a large amount of free ammonia, probably derived from soot, and it appears to be harmless.

Deep wells often show a large amount of free ammonia and chlorides without necessarily indicating pollution; but the same amounts in a shallow well would point to probable sewage pollution, or at least to the presence of urine.

The presence of a considerable amount of albuminoid ammonia, with little free ammonia and chlorides, is generally indicative of vegetable organic matter, often peaty. This is the character of the greater part of the water supply of Ireland.

The real significance of the albuminoid ammonia has been much discussed, but the results obtained are sufficiently uniform to give us a convenient measure of purity, provided we are careful not to draw the line too close. All the nitrogen of the organic matter is certainly not obtained by this method, but this is immaterial so long as the proportion is fairly maintained. The results correspond to a certain extent with the *organic nitrogen* of Frankland, and the process is much more feasible for medical officers generally.

4. *Nitric and Nitrous Acids in Nitrates and Nitrites.*—The significance of these is very important. Nitric acid is the ultimate stage of oxidation of nitrogenous organic matter, and when present in water it is almost always the result of previous pollution, either of the water itself or of the strata through which it flows. It gives us no information, however, as to the exact time when the pollution took place. In some samples from deep wells it is evident that the pollution must have been very ancient. It has been distinctly shown by Schloesing and Muntz[1] and by R. Warington[2] that nitrification is a fermentative process, excited and carried on through the agency of a minute organism, just as ordinary fermentation is carried on through the medium of *torula*. Nitrous acid indicates the presence of organic matter undergoing change: it is either a stage in the direct oxidation of such matter, progressive or arrested, or a retrogression from nitric acid in consequence of the latter having yielded up a part of its oxygen. In this way nitrous acid might retrograde still further and become converted again into ammonia, or be dissipated as nitrogen. Nitrous acid is a much more important substance than nitric, as indicating present danger, and a very small amount of it is sufficient to remove a water into the suspicious class. It is rare to find any of the higher forms of life in a water rich in nitrites, although *bacteria* may be found. Pure water ought to be quite

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[1] *Comptes Rendus*, lxxxiv. 301; lxxxv. 1018; lxxxvi. 802; lxxxix. 801, 1074.
[2] *Chem. Soc. Jour.*, 1878, xxviii. 44; 1879, 429. *Chem. News*, xliv. 217.

free from nitrites, and ought to show only traces at most of nitrates,—the limit being about 0·032 per 100,000 of nitric acid, representing of combined nitrogen 0·014 per 100,000. The total combined nitrogen (including that in the free ammonia) would be 0·016 per 100,000; whilst the total nitrogen (including that in the albuminoid ammonia) would be 0·023 per 100,000. The *presence* of nitrites is suspicious: the marked presence of nitrates ought to be a ground for careful inquiry. In some soils, especially sands and gravels, and in ferruginous soils, the process of nitrification goes on extremely rapidly, and the existence of impurity may escape notice if the examination for nitric acid be omitted.

5. *Oxygen absorbed.*—This ought not to exceed about 0·0250 per 100,000 for organic matter alone,—that is, after deducting any that may be absorbed by nitrous acid if present. This latter, however, should not be present in a water of the first class. The experiment to be done with permanganate and acid at a temperature of 140° Fahr. (60° C.).

Frankland and Wigner allow four times the above amount for upland surface waters, and double the above amount for other waters,—the experiment being performed for four hours at a temperature of 80° Fahr. (27° C.).

In water with little chlorine and little or no free ammonia, a higher amount than the above may be present without danger, as in all probability it will be due to vegetable matter.

6. *Hardness.*—The fixed hardness should not exceed 3° of the metrical scale. The total hardness may vary more, but if possible should not exceed 7° to 8°·5 (metrical).

7. *Phosphates.*—The presence of these in any marked quantity will generally corroborate inferences as regards sewage contamination drawn from the other indications.

Sulphates.—An excess of sulphates will in many cases also indicate contamination, though they may, like chlorine, come from innocuous sources.

8. *Metals.*—Pure water should contain no *heavy metal*, although a trace of iron may be found sometimes. In some cases iron seems beneficial, as it helps to oxidise the organic matter. The presence of any other *heavy metal* ought to condemn the water.

9. The presence of *hydrogen sulphide* or *alkaline sulphides* ought to condemn the water.

It is always advisable to get information if possible as to the *usual* composition of a water to be examined, as even slight variations may suggest a clue to the nature or cause of an impurity. The microscopic examination of the sediment ought always to be performed where possible, as it often affords important information when the chemical investigation fails. Thus, the presence of such objects as muscular fibre, wheaten starch cells, spiral vegetable fibres, mucous epithelium, disintegrating masses of paper, &c. are sufficient alone to condemn water (especially if it be from a shallow well), even when the chemical constituents are within limits, as they are undoubted evidences of animal contamination, almost certainly sewage. In such cases the nitric acid is nearly always large in amount.

10. *Form of Report.*—This is immaterial, so long as the facts are set forth clearly and the conclusions drawn stated distinctly. On p. 707 will be found the Form at present in use at Netley, which may serve as a guide.

The following tables give an approximate view of the composition of drinking waters of the four classes :—

1. *Pure and Wholesome Water.*

Character or Constituents.			Remarks.
Physical characters, . .	Colourless, or bluish tint; transparent, sparkling, and well aërated; no sediment visible to naked eye; no smell; taste palatable.		Turbidity, due to very fine mineral matter, is sometimes associated with pure waters; thus, minutely divided calcium sulphate will not subside in distilled water.
Chemical Constituents.	Grains per gallon, 1 in 70,000.	Centigrammes per litre, 1 in 100,000.	
1. Chlorine in chlorides, *under*	1·0000	1·4000	This may be exceeded if from a purely mineral source.
2. Solids in solution: total, *under*	5·0000	7·1428	The solids may be exceeded in chalk waters, where they are mostly calcium carbonate.
,, ,, volatile, *under*	1·0000	1·4000	
N.B.—The solids on incineration should scarcely blacken.			
3. Ammonia, free or saline, *under*	0·0014	0·0020	
,, albuminoid, *under*	0·0035	0·0050	
4. Nitric acid (NO_3), . *under* in nitrates.	0·0226	0·0323	
Nitrous acid (NO_2), . . in nitrites.	nil	nil	
Nitrogen in nitrates, *under*	0·0100	0·0140	
Total combined nitrogen, including that in the free ammonia, . . *under*	0·0112	0·0160	
Total nitrogen, including that in the albuminoid ammonia, . . *under*	0·0160	0·0230	
5. Oxygen absorbed by organic matter within half an hour, by permanganate and acid at 140° F. (60° C.), *under*	0·0175	0·0250	The oxygen absorbed may be *doubled* in peat or upland surface waters.
Do. do. in 15 minutes, at 80° F. (27° C.), . *under*	0·0100	0·0125	
Do. do. in 4 hours at 80° F. (27° C.) . *under*	0·0350	0·0500	
6. Hardness, total, . *under*	6°·0	8°·5	
,, fixed, . *under*	2°·0	3°·0	
7. Phosphoric acid in phosphates,	traces		
Sulphuric acid in sulphates,	traces		
8. Heavy metals, . . .	nil		
9. Hydrogen sulphide, alkaline sulphides, . . .	nil		
Microscopic characters, .	Mineral matter; vegetable forms; with endochrome; large animal forms; no organic debris.		See remarks on biological experiments in text.

A water such as the above may generally be used with confidence, in the absence of any history of possible pollution, or of any recent and appreciable change in the amount of the organic constituents.

2. *Usable Water.*

Character or Constituents.			Remarks.
Physical characters, . .	Colourless or slightly greenish tint; transparent, sparkling, and well-aërated; no suspended matter, or else easily separated by coarse filtration or subsidence; no smell; taste palatable.		In some usable waters, such as peat waters, the colour may be yellow or even brownish. In some also the taste may be flat or only moderately palatable.
Chemical Constituents.	Grains per gallon, 1 in 70,000.	Centigrammes per litre, 1 in 100,000.	
1. Chlorine in chlorides, *under*	3·0000	4·2857	This may be much larger in waters near the sea, deep-well waters, or waters from saline strata.
2. Solids in solution: total, *under*	30·0000	42·8571	
,, ,, volatile, *under*	3·0000	4·2857	The solids may blacken, but no nitrous fumes should be given off.
3. Ammonia, free or saline, *under*	0·0035	0·0050	This may be greater in deep-well waters.
,, albuminoid, *under*	0·0070	0·0100	This may be larger in upland surface waters, peat waters, &c., when the source is chiefly vegetable.
4. Nitric acid (NO_3), . *under* in nitrates.	0·3500	0·5000	The amount of nitrates varies greatly, so that an average is of doubtful value.
Nitrous acid (NO_2), . . in nitrites.	nil	nil	
Nitrogen in nitrates, *under*	0·0790	0·1129	
Total combined nitrogen, including that in free ammonia, . . . *under*	0·0819	0·1170	
Total nitrogen, including that in albuminoid ammonia, . . . *under*	0·0876	0·1252	
5. Oxygen absorbed by organic matter within half an hour, by permanganate and acid, at 140° F. (60° C.), *under*	0·0700	0·1000	The oxygen absorbed may be greater (about *double*) in upland surface waters, peat waters, &c.
Do. do. in 15 minutes, at 80° F. (27° C.), . *under*	0·0210	0·0300	
Do. do. in 4 hours, at 80° F. (27° C.), . . *under*	0·1050	0·1500	
6. Hardness, total, . *under*	12°·0	17°·3	
,, fixed, . *under*	4°·0	5°·7	
7. Phosphoric acid in phosphates,	traces	traces	
Sulphuric acid in sulphates, . . . *under*	2·000	3·0000	In some waters the amount may be larger.
8. Heavy metals—Iron, . .	traces	traces	
9. Hydrogen sulphide, alkaline sulphides, ...	nil	nil	
Microscopic characters, . .	Same as No. 1.		

A water such as the above will in most cases be usable, but it will be improved by filtration through a good medium.

3. *Suspicious Water.*

Character or Constituents.			Remarks.
Physical characters,	Yellow or strong green colour; turbid; suspended matter considerable; no smell, but any marked taste.		Where the impurity is mostly vegetable, the colour may be very marked in usable water.
Chemical Constituents.	Grains per gallon, 1 in 70,000.	Centigrammes per litre, 1 in 100,000.	
1. Chlorine in chlorides,	3 to 5	4 to 7	In some cases the chlorine may be greater.
2. Solids in solution: total,	30 to 50	43 to 71	
,, ,, volatile,	3 to 5	4 to 7	
3. Ammonia, free or saline,	0·0035 to 0·0070	0·0050 to 0·0100	
,, albuminoid,	0·0070 to 0·0087	0·0100 to 0·0125	
4. Nitric acid (NO_3), in nitrates.	0·35 to 0·70	0·5 to 1·0	
Nitrous acid (NO_2), in nitrites.	0·0350	0·0500	
Nitrogen in nitrates and nitrites,	0·0870 to 0·1661	0·1243 to 0·2373	
Total combined nitrogen, including that in free ammonia,	0·0871 to 0·1718	0·1247 to 0·2455	
Total nitrogen, including that in albuminoid ammonia,	0·0879 to 0·1726	0·1255 to 0·2465	
5. Oxygen absorbed by organic matter within half an hour by permanganate and acid, at 140° F. (80° C.),	0·0700 to 0·1050	0·1000 to 0·1500	
Do. do. in 15 minutes, at 80° F. (27° C.),	0·0350 to 0·0700	0·0500 to 0·1000	
Do. do. in 4 hours, at 80° F. (27° C.),	0·1500 to 0·2800	0·2000 to 0·4000	
6. Hardness, total, *above*	12°·0	17°·0	
,, fixed, *above*	4°·0	5°·7	
7. Phosphoric acid in phosphates,	heavy	traces	
Sulphuric acid in sulphates, *above*	2·000	3·000	This may sometimes be larger.
8. Heavy metals—iron,	traces	traces	
9. Hydrogen sulphide, alkaline sulphides,	nil	nil	
Microscopic characters,	Vegetable and animal forms more or less pale and colourless; organic debris; fibres of clothing, or other evidence of house refuse.		

A water such as the above ought to excite suspicion; its use ought to be suspended until inquiries about it can be made; if it must be used, it ought to be boiled and filtered.

4. *Impure Water.*

Character or Constituents.			Remarks.
Physical characters, . . .	Colour yellow or brown; turbid, and not easily purified by coarse filtration; large amount of suspended matter; any marked smell or taste.		Dark-coloured waters may be usable when the impurity is vegetable.
Chemical Constituents.	Grains per gallon, 1 in 70,000.	Centigrammes per litre, 1 in 100,000.	
1. Chlorine in chlorides, *above*	5·0000	7·1428	Chlorides *per se* are not hurtful, unless they are magnesian or in some quantity.
2. Solids in solution: total, *above*	50·0000	71·4285	
,, ,, volatile, *above*	5·0000	7·1428	
3. Ammonia, free or saline, *above*	0·0070	0·0100	
,, albuminoid, *above*	0·0087	0·0125	
4. Nitric acid (NO_3), . *above* in nitrates.	0·7000	1·0000	Some waters which are organically pure contain a great excess of solids.
Nitrous acid (NO_2), . *above* in nitrites.	0·0350	0·0500	
Nitrogen in nitrates and nitrites, . . *above*	0·1690	0·2415	
Total combined nitrogen, including that in free ammonia, . . *above*	0·1748	0·2497	
Total nitrogen, including that in albuminoid ammonia, *above*	0·1821	0·2601	
5. Oxygen absorbed by organic matter within half an hour by permanganate and acid, at 140° F. (60° C.), *above*	0·1050	0·1500	In the absence of free ammonia, or much chlorine, this may be due to vegetable matter.
Do. do. in 15 minutes, at 80° F. (27° C.), . *above*	0·0700	0·1000	
Do. do. in 4 hours, at 80° F. (27° C.), . *above*	0·2800	0·4000	
6. Hardness, total, . *above*	20°·0	28°·5	
,, fixed, . *above*	6°·0	8°·7	
7. Phosphoric acid in phosphates,	very hea	vy traces.	
Sulphuric acid in sulphates, *above*	3·000	4·2857	
8. Heavy metals, . . .	any ex	cept iron.	
9. Hydrogen sulphide, . . Alkaline sulphides, . .	pre	sent.	
Microscopic characters, . .	*Bacteria* of any kind; *fungi*; numerous vegetable and animal forms of low types; epithelia or other animal structures; evidences of sewage; ova of parasites, &c.		*N.B.*—The inferences to be drawn from *biological* examination (cultivation of minute organisms in nutrient media) are still too uncertain to enable any definite rules to be laid down. Generally speaking, the fewer organisms the better, especially when they liquefy the gelatine or other medium in which they are grown.

A water such as the above ought to be absolutely condemned. Should stress of circumstances compel its use, it ought to be well boiled and filtered, or, better still, distilled.

The following is the form of Report at present used at Netley :—

LABORATORY, ARMY MEDICAL SCHOOL, NETLEY.

Analysis of a Sample of Drinking Water.

From	Drawn Received Examined	18 18 18

Physical Characters.	*Qualitative Examination.*
Colour	Lime . . . . .
Turbidity	Magnesia . . . .
Sediment	Chlorine. . . . .
Lustre	Sulphuric acid . . .
Taste	Phosphoric acid . . .
Smell	Ammonia . . . . .
	Nitric acid . . . .
Hardness [in parts per 100,000].	Nitrous acid . . . .
Total... ....Fixed.........Removable.........	Oxidisable matter . . .
	Metals . . . . .

Quantitative Examination.

	Parts per 100,000.			Parts per 100,000.
Volatile matter . . .			Oxygen required for organic matter	
Chlorine		N.B.—These constituents, with the oxidisable organic matter, indicated by the oxygen required, are included in the *Volatile Matter*.	Free ammonia .	
Calcium carbonate . .			Albuminoid ammonia .	
Fixed Hard Salts . .			Nitric acid (NO_3) . .	
Sulphuric acid (SO_4) . .			Nitrous acid (NO_2) . .	
Alkaline carbonates . .			Total Nitrogen included in Nitrites and Nitrates	
Sodium or other metal (combined with Cl or SO_4) not included in Fixed Hard Salts . . .				
Silica, Alumina, Iron, &c. .				
Total Solids (by evaporation)				

Microscopic Examination.

Report.

[*Date*] [*Signature of Reporter.*]

CHAPTER II.

SECTION I.

EXAMINATION OF THE AIR.

1. By the Senses.

Many impurities are quite imperceptible to smell, but it so happens that animal organic matters, whether arising in respiration or in disease, have, for the most part, a peculiar fœtid smell, which is very perceptible to those trained to observe it when they enter a room from the open air. This is, in fact, a most delicate, as well as a ready way of detecting such fœtid impurities, and, with a little trouble, the sense of smell may be cultivated to the point of extreme acuteness. Only, it must be remembered, that in a short time the impression is lost, and is not at once regained even in the open air. For a detailed consideration of this question, see Dr de Chaumont's papers in the *Proceedings of the Royal Society*, 1875 and 1876. Among other points, it is shown that the humidity of the air has a very marked influence in rendering the smell of organic matter perceptible, even more powerful than a rise in temperature. Thus the effect of an increase of *one per cent.* in the humidity is as great as a rise of 4°·18 Fahr. (2°·32 C.) in temperature, calculated from the mean of 458 fully recorded observations.[1]

As the evidence of the senses, however practically useful, is always liable to be challenged, a more thorough examination of the air must in many cases be made.

2. Microscopical and Chemical Examination.

The points which should be examined are [2]—

1. The existence and character of suspended matters as judged of by the microscope, both by immediate observation and after cultivation in prepared nutrient fluids.[3]
2. The amount of CO_2, which is taken as a convenient measure of all impurities.
3. The amount of the free or saline ammonia.
4. The ammonia formed by the action of alkaline permanganate on nitrogenous substances floating in the air (albuminoid ammonia).[4]
5. The amount of oxidisable substances, as judged of by the amount of oxygen given off by a standard solution of potassium permanganate.[4]

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[1] Supplementary Note on the Theory of Ventilation, *Proceedings of the Royal Society*, Nov. 17, 1876.

[2] The amounts of oxygen and nitrogen can also be determined; but very numerous observations have shown that the oxygen often varies within extremely narrow limits, even when there is no doubt of the presence of considerable impurity in the air, so that, as far as present knowledge goes, the determination of its amount is no good guide as a general rule.

[3] On this question, see Tyndall on *Floating Bodies in the Atmosphere*; Miquel, *Annuaire de Montsouris*, 1882; and Fodor, *Die Luft*, *op. cit.*

[4] For these two processes the determination of the organic nitrogen and carbon, by Frankland's method, may be substituted, if practicable.

6. Amount of nitrous and nitric acids.
7. The amount of watery vapour.
8. The presence of H_2S, or other offensive gases and vapours.
9. The presence or absence of ozone.

Microscopical Examination.

1. *Suspended Matters.*[1]—It is probable that the microscopical examination of air will give us in future more important information even than the chemical examination. It is, of course, merely a qualitative test, as there are no satisfactory means of properly estimating the amount collected.

The suspended matters may be collected very simply by Pouchet's aeroscope. A small funnel is drawn into a small point, below which is a slip of glass moistened with glycerine. The end of the funnel and the slip of glass are inclosed in an air-tight chamber, from which a small glass tube passes out and is connected by india-rubber tubing with an aspirator. As the water runs out through the aspirator, air passes down the funnel and impinges on the glycerine, which arrests any solid particles.

As it is, however, desirable to avoid glycerine, which may (in spite of previous careful examination) contain foreign particles, a still better plan is to take a small bent tube, wash it thoroughly, dry it, and heat it to redness; when cool, it should be placed in a freezing mixture, an india-rubber tube fixed on one end, and air slowly drawn through; the water of the air condenses in the tube, and many of the solid particles fall with it. A drop is then taken by a perfectly clean glass rod, previously heated to redness, placed on a clean glass, and looked at with an immersion lens, as soon after collection as possible.

Or air may be drawn through pure distilled water, a drop of which is then examined.

The late Dr Watson (Staff-Surgeon), in his examination of the air at Netley,[2] used fine glass threads soaked in pure glycerine, or dry, and crushed glass; after the air was drawn through, he washed the glass threads with pure water, and then examined the water. These glass threads form good traps for the larger particles.[3] For thorough investigation, however, it is necessary to carry out cultivation experiments, by carrying the air through a sterilised solution, and watching carefully the development of the different organisms. Fodor recommends a solution of isinglass, $1\frac{1}{2}$ to 2 parts in 300 to 400 of pure distilled water, thoroughly boiled, and decanted or filtered.

Miquel has employed a variety of media, some proving more convenient than others for different purposes.

An aspirator, to draw air through the tubes, is very easily made; a square tin vessel, with a tap below, and a small opening above to receive the india-rubber tube, is all that is necessary; fill this with water, and let it run down, and measure the total quantity (in a pint vessel) discharged without tilting the vessel. An imperial pint contains 34·659 cubic inches, and one fluid ounce 1·733 cubic inches. A cubic foot is very nearly 1000 fluid ounces, and the ounce may be taken as 1·728 cubic inches.[4] The exact delivery of the aspirator is, therefore, easily determined; the air should be drawn slowly through the bent tube in the freezing mixture or through the

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[1] See pages 133–9, for an account of the suspended matters in air.
[2] *Army Medical Department Reports*, vol. xi. p. 529.
[3] I have found carrying the air through a succession of bottles containing pure distilled water the best plan, for the sediment is examined by the microscope, and the liquid part can be used for chemical examinations for organic matter.—(F. de C.)
[4] These numbers are exact at 39° Fahr., or the maximum density point of water.

aeroscope, so that no particles can escape. The use of a large glass or earthenware vessel is perhaps better, as being less liable to error; a piece of india-rubber with a clamp or pinch cock, and a double tubed india-rubber cap, are all that are required.

Chemical Examination.

2. *Estimation of Carbon Dioxide.*—For our purpose the method proposed by Pettenkofer is the best. A glass vessel is taken capable of holding a gallon, or 4½ litres. The capacity is determined by filling it with water, and by measuring the contents by means of a litre or pint measure (1 oz. = 28·4 cubic centimetres). Angus Smith recommends extracting the air from the bottle by means of bellows. But the most convenient way is simply to fill the vessel with water in the place, the air of which is to be examined, and then to let it drain for a little. When this is done 60 c.c. of clear lime or baryta water are put in, and the mouth is closed with an india-rubber cap.[1] The vessel is agitated so that the lime-water may run over the sides, and then it is left to stand for not less than six or eight hours if lime-water be used; if baryta-water be used, the experiment may be completed in a much shorter time—less than one hour. The CO_2 is absorbed by the lime or baryta-water, and consequently the causticity of these fluids is, *pro tanto*, lessened. If the causticity of the lime or baryta is known before and after it has been placed in the vessel, the difference will give the amount of lime or baryta which has become united with CO_2.

The causticity of lime is determined by means of a solution of crystallised oxalic acid,[2] 1 c.c. of which exactly neutralises 1·26 milligramme (0·00126 gramme) of lime and is equal to 0·5 c.c. of CO_2; 30 c.c. of lime water are taken, and exactly neutralised; good turmeric paper is the best plan that is usually available for determining the exact point of neutralisation, and the margin of the drop gives the most delicate indication. Rosolic acid has, however, been recommended, and also the solution of phenol-phthalein; the latter gives very exact indications. The amount of lime in the 30 c.c. is then equal to the number of c.c. of the oxalic acid used × 1·26; it is always somewhere between 34 and 41 milligrammes, or between 27 and 33 c.c. of oxalic acid solution, each equal to 0·5 c.c. of CO_2.[3]

After the lime has absorbed the CO_2 of the air in the vessel, 30 c.c. of the solution are taken out and tested with the oxalic acid solution as before; the difference shows the c.c. of CO_2 which have been absorbed by the lime. Deduct 60 c.c. from the total capacity of the jar (to account for the space occupied by the lime-water put in), and state the capacity in litres and decimals: divide the c.c. of CO_2 obtained by the corrected capacity of the jar; the quotient is the c.c. of CO_2 per 1000 volumes of air.

Example.—The first alkalinity of lime-water was,	30 for 30 c.c.
After exposure to the air in the jar it was, ...	26 ”
Difference, being c.c. of CO_2, . .	4 = Total CO_2 in jar in c.c.

[1] Should an india-rubber cap not be available, a cork or a bung may be used, tied over with leather or oil-skin; in that case the second alkalinity of the lime-water (if this be used) should be determined as soon after the six or eight hours as possible, certainly within twenty-four hours.

[2] See Appendix A.

[3] The amount varies with the temperature, lime being less soluble in hot than cold water: at 60°·7 the amount is 38·6 with a difference of +0·1 for every degree below that, and −0·1 for every degree above (Fahr.).

That is, each c.c. of oxalic acid solution represents 0·5 c.c. of CO_2, but, as 60 c.c. of solution were put in the jar, the result is multiplied by 2 to account for the remaining 30.

Capacity of jar, ...	4385 c.c.
Deduct 60 c.c. for space taken up by lime-water,	60
Net capacity, ...	= 4325 c.c. = 4·325 litres.

Then $4 \div 4{\cdot}325 = 0{\cdot}925$ c.c. of CO_2 per litre, or volumes per 1000.

If baryta be used instead of lime, it must be free from traces of potash and soda; a much smaller quantity of liquid may be employed, as it is so much more soluble than lime; the calculation is the same.

A correction for the temperature of the air examined must be made, the standard being 32° Fahr., or 0° C., the freezing-point of water. If the temperature be above this (as it will generally be, at least in buildings) the air will be expanded, and a smaller quantity, by weight, consequently will be operated on. On the other hand, below 32° the air will be contracted, and a larger quantity, by weight, operated on than at the standard temperature. This can be corrected by adding 0·2 per cent. to the result for every degree above 32°, and subtracting it for every degree below; the reason being that air expands or contracts 0·2 per cent. for every degree (or 1 per cent. for every 5 degrees) it deviates from the standard. If stated in centigrade degrees, then the correction is 1·1 per cent. for every 3°, or 0·3665 per cent. for every degree.

Example.—In the preceding example the CO_2 was found to be 0·925 per 1000. Suppose the temperature to have been 60° Fahr., then $60 - 32 = 28°$ to be corrected for; $28 \times 0{\cdot}2 = 5{\cdot}6$ per cent. to be added on to the result, or the result must be multiplied by $1 + {\cdot}056 = 1{\cdot}056$, $\therefore 0{\cdot}925 \times 1{\cdot}056 = 0{\cdot}977$ per 1000, the corrected result. Suppose the temperature had been 25° Fahr., then $32 - 25 = 7°$ to be corrected for; $7 \times 0{\cdot}2 = 1{\cdot}4$ per cent. to be deducted, or the result must be multiplied by $1{\cdot}00 - {\cdot}014 = 0{\cdot}986$, $\therefore$ $0\ 925 \times 0{\cdot}986 = 0{\cdot}912$, the corrected result.

A correction for pressure is not necessary, as $\frac{1}{10}$ inch of pressure causes a difference of only 0·26 per cent., unless the place of observation be much removed from sea-level; in that case, the barometer must be observed, and a rule of three stated.

$$\text{As standard height of bar:} \left\{\begin{matrix} \\ (=29{\cdot}92 \text{ in.} = 760 \text{ mm.}): \end{matrix}\right\} : \left\{\begin{matrix}\text{observed height} \\ \text{of bar:}\end{matrix}\right\} :: a : x,$$ where a = CO_2 corrected for temperature, and $x = CO_2$ corrected for temperature and pressure.

Example 1. Barometer at 27·25:—

$$29{\cdot}92 : 27{\cdot}25 :: 0{\cdot}925 : x = 0{\cdot}842.$$

Example 2. Barometer at 31·5:—

$$29{\cdot}92 : 31{\cdot}5 :: 0{\cdot}925 : x = 0{\cdot}974.$$

It must be understood that none of the methods hitherto used for the determination of CO_2 in the air give quite accurate results, but the above is the most convenient for ordinary use, and is sufficiently accurate for practical purposes. The results differ considerably if the quantities of air treated vary, therefore uniformity in this point is desirable.

Dr W. Hesse (of Schwarzenberg) has devised an ingenious portablo apparatus for determination of CO_2, but the quantities of air treated seem rather too small. The box or satchell includes the various apparatus

necessary for measuring cubic space, determining air currents, ascertaining the CO_2, and observing the humidity (by Wolpert's hygrometer).

3. and 4. *Estimation of Free Ammonia and of the Nitrogenous Matter in Air by conversion into Albuminoid Ammonia.*—The nitrogenous matter existing in air may be in the form of dead or living matter of very various kinds. Its determination may be useful as showing that one or other of these classes of substances exists in the air in proportions greater than in pure air. The amount of nitrogen may be estimated in a similar manner to that proposed by Wanklyn and Chapman for water. The late Mr Chapman,[1] finding that water did not sufficiently absorb the nitrogenous substances in air, proposed to heat finely powdered pumice-stone to redness, to moisten it with pure water, and then to place it over some coarse pieces of pumice-stone supported on wire in a funnel; a definite quantity of air (say 100 litres) is then drawn through the funnel; the pumice-stone is transferred to a retort containing water freed from ammonia, and distilled as in the determination of the albuminoid ammonia of water. Dr Angus Smith[2] took a bottle of about 2000 c.c. capacity, placed in it 30–50 c.c. of the purest water, drew into it the air to be examined, and then agitated the water in the bottle, and proceeded as in Wanklyn's and Chapman's water test. The most convenient way is to draw the air, by means of a measured aspirator, through a succession of wash bottles, each containing 100 c.c. of water, perfectly free from ammonia, and then to determine the free and albuminoid NH_3 by Wanklyn's method.

Another plan is to lead a definite quantity of air through a clean curved tube, surrounded by a freezing mixture; the water of the air condenses, and with it much of the organic matter; the tube is then washed out with pure water, the washings are put into a retort with ammonia-free water, and distilled as usual. After passing through the tube the air should be led through pure water to arrest the portion of organic matter that always escapes condensation.

The amount of ammonia (free and albuminoid) is determined as in water analysis. The mere presence of free ammonia may be determined by exposing strips of filtering paper, dipped in Nessler's solution or in etherial solution of the alcoholic extract of logwood: the former becomes yellow, the latter purple.

The quantity of air drawn through must, of course, be accurately determined by a properly arranged aspirator, and the results then calculated in milligrammes per cubic metre.[3]

5. *Estimation of the Oxidisable Matters in the Air in terms of Oxygen.*—In this case a definite quantity of air is drawn through a solution of permanganate of potassium of known strength, and the amount of undecomposed permanganate is determined by oxalic acid or sodium hyposulphite. Or part of the water through which the air has been drawn for the ammonia determinations may be examined in the same way as in the case of drinking water. Carnelley and Mackie shake the air up in a bottle with a measured quantity of permanganate, and afterwards determine the amount of bleaching by comparision with a sample of distilled water, to which permanganate solution is carefully added from a burette.[4] The permanganate acts upon various matters in the air, besides the putrescible organic matters, such as hydrogen sulphide, nitrous acid, tarry matters, &c. The presence or absence of H_2S may be determined qualitatively by means of acetate of lead papers,

[1] *Chemical News*, Feb. 11, 1870. [2] *Air and Rain*, p. 421.
[3] One cubic metre equals 1000 litres, or 1,000,000 c.c.
[4] *Proc. Royal Soc.*, vol. xli. p. 238.

ammonium sulphide by paper dipped in nitroprusside of sodium; whilst tarry matters would generally be recognised by the smell of the water, or its turbidity. In the absence of these the difference between the permanganate determinations, before and after boiling with sulphuric acid, may be calculated as nitrous acid, as in the case of drinking water; whilst the result after boiling may be reckoned as the oxygen for oxidisable organic matter only.[1]

6. *The Nitrous and Nitric Acids* may also be determined, in the same way as in drinking water, from the washings of the air obtained as above.

All these determinations should be made, when opportunities offer, as the results may prove hereafter of some value.

7. *Watery Vapour.*—The hygrometric condition of the air is ascertained in various ways, especially by the dry and wet bulb thermometer, or by Dines' direct hygrometer. The hair hygrometer of Saussure is also a useful instrument for this purpose, as it marks the degree of humidity very quickly. Wolpert's horse-hair hygrometer may also be used.

8. The presence of H_2S, &c., has been referred to above.

SECTION II.

SCHEME FOR THE APPLICATION OF THE FOREGOING RULES.

When a ventilation inquiry is about to be made, everything ought to be got ready beforehand. A number of bottles (about 4 to 4½ litres), or glass jars, ought to be carefully measured, and the capacity in c.c. (less 60 c.c. to account for the lime-water) marked upon them; each bottle ought also to have a closely fitting india-rubber cap and a distinctive number. These bottles are to be used for collecting the samples of air for CO_2. Charges of lime-water (or baryta-water) (each 60 c.c.) ought to be carefully measured off with a burette, or graduated pipette, into small stoppered bottles. Two or more sets of wet and dry bulb thermometers ought to be ready, and two or more series of not less than six bottles, each containing about 100 c.c. of pure distilled water, connected together with glass tubes and india-rubber caps; also four or more aspirators for drawing the air through the bottles. One of Casella's small air meters, with a long pole in joints, into which it can be screwed, a measuring tape and foot rule, a pocket compass, some pieces of cotton-velvet, a note-book, are also necessary.

When a room has to be examined, enter it after being some time in the open air, and notice if there be any smell; record the sensation at once in your notes. Hang up the wet and dry bulb thermometer (if it has not been placed there before), and then proceed to take samples of the air for CO_2; fill the jars with water, empty them, and allow them to drain; then pour into each jar the lime-water from one of the small bottles, put on the india-rubber cap, and shake it up. Always take *two* samples at least, and more if a large room. Note the numbers of the bottles. Take the wet and dry bulb readings. Arrange the set of bottles with distilled water in some convenient place, and attach them to one of the aspirators, which may be allowed to flow into another below it. When the upper one is empty it may be changed for the lower one, and so the stream of air may be carried on for any length of time, as seems necessary; the number of times the aspirators are changed should be duly noted. In determining the carbon

[1] See *Reports on St Mary's Hospital*, by Dr F. de Chaumont.

dioxide, put out all the lights, or have only sufficient for working purposes; allow no smoking, and have no person in the room but those who are sleeping there. The aspirators may be allowed to go on continuously, but the examination of the air for CO_2 ought to be repeated at intervals, the exact time of observations being noted. At the same time, similar observations ought to be made in the open air, as nearly as possible simultaneously with those inside. At some convenient time the measurements of the room and the ventilators, the velocities of the currents of air, &c., should be taken on some such plan as the following:—Measure the cubic space, then consider the possible sources of entrance and exit of air; if there are only doors and windows, notice the distance between them, how they open, on what external place they open; whether there is free passage of air from side to side; whether it is likely the air will be properly distributed. On all these points an opinion is soon arrived at. If there are other openings, measure them all carefully, so as to get their superficies; the chimney must be measured at its throat or smallest part. Determine then the direction of movement of air through these openings by smoke, noting the apparent rapidity. The doors and windows should be closed. When the inlets have been discovered, consider whether the air is drawn from a pure external source, and whether there is proper distribution in the room. Then measure the amount of movement in both inlets and outlets with the anemometer, or calculate by the table if it seems safe to do so.

If the ventilation of the room is influenced by the wind, the horizontal movement of the external air should be determined by Robinson's anemometer, or the little air-meter by Casella may be also used for this purpose, unless the wind be very strong.

In recording the velocity of the air at any openings, it is convenient to mark an incoming current with a *plus* sign, and an outgoing with a *minus*, thus: + 75 would mean an incoming current at the rate of 75 feet per minute; whilst – 63 would mean an outgoing current at 63 feet per minute.

When the final analyses are made, and the amount of CO_2 determined, the amount of air per head per hour, supplied and utilised, ought to be calculated out (as before explained), and compared with the amount of movement determined with the air-meter. If the quantities accord fairly, the distribution may be considered good; on the other hand, if they differ, an excess by the air-meter shows bad distribution, whilst a deficiency indicates some other source of incoming air not yet observed.

The water, through which the air has been passed by the aspirator, ought to be examined at once, if practicable; if not, the bottles ought to be carefully stoppered, and the stoppers tied down with leather or strong linen,—when convenient, the sediment should be examined microscopically, and the water (when the sediment has subsided) chemically as before explained. The sediment or a portion of the water should be put into a cultivating solution for further investigation, if opportunity affords.

CHAPTER III.

EXAMINATION OF FOOD AND BEVERAGES.

SECTION I.

EXAMINATION OF FLOUR FOR QUALITY AND ADULTERATION.

Flour[1] should be examined physically, microscopically, chemically, and practically by making bread.

The quality is best determined by chemical examination; adulterations by the microscope, for which see BOOK I., under FLOUR.

1. *Physical Examination.*

Sight.—The flour should be quite white, or with the very slightest tinge of yellow; any decided yellow indicates commencing changes; the amount of bran should not be great.

Touch.—There should be no lumps, or, if there are, they should at once break down on slight pressure; there must be no grittiness, which shows that the starch grains are changing, and adhering too strongly to each other, and will give an acid bread. There should, however, be a certain amount of adhesion when a handful of flour is compressed, and if thrown against a wall or board some of the flour should adhere. When made into a paste with water, the dough must be coherent, and draw out easily into strings.

Taste.—The taste must not be acid, though the best flour is slightly acid to test-paper. An acid taste, showing lactic or acetic acid, is sure to give an acid bread.

Smell.—There must be no smell of fermentation or mouldiness.

Age of flour is shown by colour, grittiness, and acidity.

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[1] The following is given by Peligot (mean of 14 analyses), as the relative composition of flour and bran. The analyses of Von Bibra (*Die Getreidearten und das Brod*, 1860) agree very closely with it.

Wheat Flour and Bran. In 100 parts.

	Flour.	Bran.
Water,	14	10·3
Fatty matters,	1·2	2·82
Nitrogenous substances insoluble in water (glutin),	12·8	10·84
Nitrogenous substances soluble in water (albumen),	1·8	1·64
Non-nitrogenous soluble substances (dextrin, sugar),	7·2	5·8
Starch,	59·7	22·62
Cellulose,	1·7	43·98*
Salts,	1·6	2·52

* This is, however, the cellulose of the entire grain, both of the husk and the interior of the grain. Potash, phosphoric acid, and magnesia are the principal ingredients of the salts; the earthy phosphates are especially combined, and in definite proportions, with the albuminoids (Mayer), and also the gummy matter (Bibra). The alkaline phosphates are free. The bran contains much silica. Oudemans places the cellulose lower (25 to 30 per cent.) and the salts higher (4 to 6 per cent.).

2. *Chemical Examination.*

It is seldom that a medical officer will be able to go through a complete examination, but he should always determine the following points :—

1. *Amount of Water.*—Weigh 1 gramme, spread it out on a dish, and dry either by a water bath or in a hot-air bath or oven, the temperature not being allowed to go above 212°. The flour must not be at all burnt or much darkened in colour. Weigh directly the flour is cold; the loss is the percentage of water.

The range of water is from 10 (in the best dried flours) to 18 in the worst. The more water the greater liability of change in the flour, and, of course, the less is the amount of nutriment purchased in a given weight. If, then, the water be over 18 per cent., the flour should be rejected; if over 16, it should be unfavourably spoken of.

2. *Amount of Glutin.*—Weigh 10 grammes and mix, by means of a glass rod, with a little water, so as to make a well-mixed dough; let it stand for quarter of an hour in an evaporating dish; then pour a little water on it; work it about with the rod, and carefully wash off the starch; pour off, from time to time, the starch water into another vessel. After a time, the glutin becomes so coherent that it may be taken in the fingers and worked about in water, the water being from time to time poured off till it comes off quite clear. If there is not time to dry the glutin, then weigh; the dry glutin is rather more than one-third the weight of the moist; 1 to 2·9 is the usual proportion; therefore divide the weight of the moist glutin by 2·9. If there be time, dry the glutin thoroughly, and weigh it. This is best done by spreading it out on a crucible lid and drying it in the bath. The dry glutin ranges from 8 to 12 per cent.; flour should be rejected in which it falls below 8. If there is much bran, it often apparently increases the amount of glutin by adhering to it, and should be separated if possible; in fact, the glutin, as thus obtained, is never pure, but always contains some bran, starch, and fat. The glutin should be able to be drawn out into long threads; the more extensible it is the better. It is always well to make two determinations of glutin, especially if there is any disputed question of quality.[1]

3. *Amount of Ash.*—Take 10 grammes,[2] put into a porcelain or platinum crucible, and incinerate to white ash. Weigh. The ash should not be more than 2 per cent., or probably some mineral substances have been added; it should not be less than 0·8, or the flour is too poor in salts.

The incineration of the flour requires a crucible and gas. It is difficult to do it over a spirit lamp, as it takes a long time. A small charcoal fire is probably the best plan when gas appliances are wanting.

If the ash be more than 2 per cent., add hydrochloric acid, and see if there be effervescence (magnesium or calcium carbonate). Dissolve, and test with oxalate of ammonium, and then for magnesia, in the same way as in water. As flour contains both lime and magnesia, to prove adulteration the precise amount of lime and magnesia must be determined by weighing the incinerated calcium oxalate, or the magnesium pyrophosphate.

If there is no effervescence add water, and test for sulphuric acid and lime, to see if calcium sulphate (plaster of Paris) has been added. In normal flour the amount of sulphuric acid is very small.

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[1] Mr Wanklyn has proposed to utilise the albuminoid ammonia process for determining glutin, reckoning that 100 parts of flour yield 1·2 of ammonia.

[2] If only a small crucible be employed a smaller quantity should be taken, as it is difficult to incinerate; with a moderately good balance, 2 or 3 grammes may be used.

Notice, also, if the ash be red (from iron). If clay has been added, it will be left undissolved by acids and water.

If magnesium carbonate has been added, the ash is light and porous and bulky (Hassall).

An easy mode of detecting large quantities of added mineral substances is given by Redtenbacher; the flour is strongly shaken with chloroform; the flour floats, while all foreign mineral substances fall. This is a very useful test.[1]

If the water be small, the glutin large, and the salts in good quantity, the flour is good, supposing nothing is detected on microscopical examination. But in all cases it is well, if time can be spared, to have a loaf made.

Practical Test by Baking.—Make a loaf, and see if it is acid when fresh, and how soon it becomes so; if the colour is good; and the rising satisfactory. Old and changing flour does not rise well, gives a yellowish colour to the bread, and speedily becomes acid. Excess of acidity can be detected by holding a piece of bread in the mouth for some time, as well as by test paper.

Test for Ergot.—There is no very good test for ergot when it is ground up with the flour. Laneau's plan is to make a paste with a weak alkaline solution; to add dilute nitric acid to slight excess, and then alkali to neutralisation; a violet-red colour is said to be given if ergot is present, which becomes rosy-red when more nitric acid is added, and violet when alkali is added.

Wittstein considers this method imperfect, and prefers trusting to the peculiar odour of propylamine (herring-like smell) developed by liquor potassæ in ergoted flour.

SECTION II.

EXAMINATION OF BREAD.

There is, perhaps, no article on which the medical officer is more often called to give an opinion.

General Characters.—There should be a due proportion, not less than 30 per cent., of crust; the external surface should be well baked, not burnt; the crumb should be permeated with small regular cavities; no parts should be heavy, and without these little cells; the partitions between the cavities should not be tough; the colour should be white or brownish from admixture of bran; the taste not acid, even when held in the mouth. If the bread is acid the flour is bad, or leaven has been used; if the colour changes soon, and *fungi* form, the bread is too moist; if sodden and heavy, the flour is bad, or the baking is in fault; the heat may have been too great, or the sponge badly set.

Chemical Examination.—This is conducted chiefly to ascertain the amount of water and acidity, and the presence of alum or sulphate of copper.

Water.—Take a weighed quantity (say 10 grammes) of crumb, and dry in a water bath; powder, and then dry again in a hot-air bath or oven, and weigh; the water should not be more than 45 per cent.; if more, the bread is *pro tanto* less nutritious, and is liable to become sooner mouldy.

Acidity.—This can be determined by a standard alkaline solution.[2]

In two samples of fresh good bread examined at Netley the percentages of acidity (reckoned as glacial acetic) were respectively 0·054 and 0·055 (3·78 and 3·85 grains per lb); in a sample rather underbaked, but fairly

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[1] The remaining ingredients can be determined, if necessary, from the starch water, but it is seldom necessary to do so. Allow the starch to subside, pour off the fluid, and wash the starch by decantation, then dry and weigh; take all the water and washings, evaporate to a small bulk, add a little nitric acid, and boil; albumen is thrown down; collect, wash, and weigh. Evaporate the whole of the remainder to dryness, and weigh (mixed dextrin and sugar).

[2] See Appendix A.

good, 0·072 per cent. (5·04 grains per ℔); and in three samples, condemned as inferior, 0·085, 0·088, and 0·104 per cent. respectively (5·95, 6·16, and 7·28 grains per ℔).[1] On another occasion, two samples of fairly good bread yielded 0·102 and 0·12 per cent. (7·14 and 8·4 per ℔ respectively); and two others, from bakers in the neighbourhood, 0·084 and 0·090 (5·88 and 6·30 per ℔ respectively). A sample condemned as sour yielded 0·18 (12·6 per ℔): 8 grains per ℔ (0·114 per cent.) ought certainly to be the limit.

Alum.—The determination of the presence of alum is not difficult, but the quantitative analysis is necessary, since it has been shown by Wanklyn that unalumed bread may contain an appreciable amount. Many processes have been proposed,[2] some of which are merely modifications of each other. The process described in the foot-note seems the most simple.[3]

Wanklyn considers that unalumed bread may contain 5 or 6 milligrammes of phosphate of aluminum in every 100 grammes of bread (=0·005 per cent.). This is equal to about $1\frac{1}{2}$ grains of crystallised alum per ℔ of bread. It will be well to deduct this amount from the total amount of phosphate of aluminum found; the remainder will represent the amount corresponding to alum added. Carter Bell[4] deducts 10 grains per 4 ℔ loaf, or $2\frac{1}{2}$ grains per ℔, before reckoning adulteration.

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1 Report on Hygiene, *Army Medical Reports*, vol. xviii. p. 222.

2 By Kuhlmann, Letheby, Odling, Wentworth Scott, Crookes, Hassall, Hadow, Horsley, Dupré, Wanklyn.

3 *1st part.*—Take at least $\frac{1}{2}$ ℔ of crumb, put it in a mortar, and soak it well in cold distilled water; filter, and get as clear a fluid as possible; add a few drops of hydrochloric acid, and then chloride of barium. If there is no precipitate no alum can have been added, and the process need not be proceeded with. If there is a slight precipitate, it may be accounted for by sulphate of lime or magnesia in the water used in baking, or by sulphate of magnesia in the salt, or by the slight amount of sulphuric acid naturally existing in the grain, or added during the grinding. Perhaps the medical officer will know whether the water or the salt contains sulphates, and if so, the absence of alum may be inferred. If there be a large precipitate, the presence of alum is probable, but is not certain, and the process must be continued.

2d part.—Dupré's process, as modified by Wanklyn, seems on the whole the simplest and least liable to error, as it gets rid of one great source of fallacy, namely, the presence of alumina in the liquor potassæ, which reagent is not required. The process is as follows:—Take 100 grammes (=$3\frac{1}{2}$ ounces) of bread; incinerate for four or five hours in a platinum dish to a grey ash; weigh (the ash should not sensibly exceed 2 grammes); moisten with 3 c.c. of pure hydrochloric acid to separate silica; add 20 to 30 c.c. of distilled water, boil, filter, wash the filter well with boiling water; add to the filtrate, which contains the phosphates of calcium, magnesium, aluminum, and iron, 5 c.c. of liquor ammoniæ (sp. gr. 880), which causes a precipitate of these phosphates; then add gradually 20 c.c. of strong acetic acid, which partially clears the fluid by dissolving the phosphates of calcium and magnesium; boil and filter. The undissolved part is a mixture of phosphate of aluminum and phosphate of iron; wash, precipitate well with boiling water, dry, ignite, and weigh.

The iron must now be determined in this precipitate. This may be done by the permanganate, but Wanklyn's colorimetric test is probably better: it is as follows:—Dissolve 1 gramme of pure iron wire in nitro-hydrochloric acid, precipitate the ferric oxide with ammonia; wash the precipitate, dissolve it in a little hydrochloric acid, and dilute to 1 litre: 1 c.c. therefore equals 1 milligramme of metallic iron; when used it is diluted 1 in 100 so as to make a solution of which each c.c. contains $\frac{1}{100}$th milligramme (=0·01 of a milligramme) of metallic iron. To use this, dissolve the phosphates of aluminum and iron (obtained by the above-described process) in pure hydrochloric acid, and dilute to 100 c.c. Test the solution to see if it give a deep colour with ferrocyanide of potassium; if the colour is not too deep take 50 c.c. of the solution, but if it be deep take a smaller quantity, and make it up to 50 c.c. with distilled water, taking care that it is well acidulated. Put it into a cylindrical glass, and add 1 or 2 c.c. of solution of ferrocyanide of potassium: a blue colour is given. Into another glass 1 c.c. of strong hydrochloric acid is put, and 50 c.c. of distilled water; 1 or 2 c.c. of ferrocyanide are added; the standard solution of iron is then dropped in till an equal colour is produced. The amount of iron is then read off and calculated as phosphate (1 of iron=2·696 $FePO_4$). Deduct the weight from the total weight of phosphate of aluminum and iron; the remainder is phosphate of aluminum (=$AlPO_4$), of which 1 part equals 0·42 alumina, or 2·1 dry or 3·9 crystallised potassium alum; or 1·9 dry or 3·7 of crystallised ammonium alum, which last is almost the only kind now in the market.

4 *Analyst*, No. 40, 1879, p. 126.

Dr Letheby also used a decoction of logwood as a test; a piece of pure bread and a piece of suspected bread are put into a glass containing freshly prepared decoction, and left for twenty-four hours; the pure bread is simply stained, the alumed bread is dark purplish, as the alum acts like a mordant. Mr Hadow and Mr Horsley[1] have also used this test with advantage, but Mr Crookes, after many experiments, came to the conclusion that it was valueless.[2] Wynter-Blyth proposes the use of slips of gelatine soaked in the aqueous solution of the suspected bread. If the bread is pure the gelatine is stained only a reddish-brown by logwood, and can be decolorised by glycerine; alumed bread gives a more or less deep blue colour, which is permanent in glycerine.

Alum is not much used except with inferior bread.[3] The amount of alum in bread is said to be, on an average, 3 ounces to a sack or 280 ℔ of flour; if the sack gives 105 4-℔ loaves, there will be 3 grains in a ℔ of bread; but if crystallised alum is meant by this, there will only be about $1\frac{1}{2}$ grains of dry alum. Hassall states the quantity to be $\frac{1}{2}$ ℔ (8 ounces) to 240 ℔ of flour, but that the quantity differs for old and new flour. A very good witness,[4] in the inquiry into the grievances of the journeymen bakers, gave the quantity at 10 ounces per sack; this would give 41·6 grains per 4-℔ loaf, or 10·4 grains per ℔. When mixed with flour and baked the alum is decomposed: part of the alumina combines most strongly with phosphoric acid; and either this or the alum itself is presumed to be in combination with the glutin; potassium disulphate is probably formed.

Cupric Sulphate.—Cut a smooth slice of bread, and draw over it a glass rod dipped in potassium ferrocyanide. If copper be present, a brick-red colour is given by the formation of ferrocyanide of copper. The test is very delicate. It is believed to be a very rare adulteration in England. It has been said that cobalt is used instead of copper, but it is also probably very rare; it can be detected by the blueness of the ash.[5]

Potatoes.—If potatoes in any quantity have been added, the ash of the bread, instead of being neutral, is alkaline; this can only occur from sodium carbonate having been added, or from the presence of some salts of organic acids,—citrates, lactates, tartrates, which form carbonates on incineration. But if it be from sodium carbonate, the solution of bread will be alkaline, so that it can be known if the alkalinity is produced during incineration. If so, it is almost certain to be from potato.

Examination of Yeast.—Common brewers' yeast is not likely to be adulterated. If any solid mineral substances are mixed with German yeast, they are detected either by washing or by incineration. Dr Letheby found German yeast, imported in 1863, to be adulterated with 30 per cent. of pipe-clay.

SECTION III.

METHOD OF EXAMINATION OF SUGAR.

1. Determine physical characters of colour, amount of crystallisation, &c.
2. Dissolve in cold water; fragments of cane, starch, sand, gypsum,

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1 *Chemical News*, May 1872. 2 *Chemical News*, Sept. 1862.

3 *Report on Journeymen Bakers*, 1862, p. 164; see also Odling's Papers. Hassall, however, found alum in half the loaves examined. A writer in the *Lancet* (Jan. 1872) states that at that date alum was found in 10 out of 20 loaves, and the amount was from 12 to 96 grains in the 4 ℔ loaf.

4 *Report on Journeymen Bakers*, 1862, p. 163. Some of the statements are beyond even this amount—1 ℔ to 4 ℔ per 1000 (4 ℔?) loaves (p. xxxvi.); but this is probably an exaggeration.

5 Dr Campbell Brown.

calcium phosphate are left behind; test with iodine for starch. The best way is to dissolve under the microscope, as all adulterations are then at once detected.

3. Determine percentage of water by drying thoroughly 10 grammes, and again weighing.

4. Excess of glucose (a little is always present) is detected by the large immediate action on the copper solution.

SECTION IV.

EXAMINATION OF MILK.[1]

This is intended first to determine the quality. Put some of the milk in a long glass, which is graduated to 100 parts; a 100-centimetre or litre measure will do, or a glass may be specially prepared by simply marking with compasses 100 equal lines on a piece of paper, and gumming it on the glass. Allow it to stand for twenty-four hours in a cupboard secured from currents of air. By this means the percentage of cream can be seen, and the presence of deposit, if any, observed. There should be no deposit till the milk decomposes; if there be, it is probably chalk or starch.

The cream should be from $\frac{6}{100}$ths to $\frac{11}{100}$ths; it is generally about $\frac{8}{100}$ths; in the milk of Alderney cows it will reach $\frac{30}{100}$ths or $\frac{40}{100}$ths. The time of year (as influencing pasture), and the breed, should be considered.

While this is going on, determine—

1. *The Physical Characters.*—Placed in a narrow glass, the milk should be quite opaque, of full white colour, without deposit, without peculiar smell or taste. When boiled it should not change in appearance.

2. *Reaction.*—Reaction should be slightly acid or neutral, or very feebly alkaline; if strongly alkaline, either the cow is diseased (?) or there is much colostrum, or sodium carbonate has been added.

3. *Specific Gravity.*—The specific gravity varies from 1026 to 1035. A very large quantity of cream lowers it, and after the cream is removed, the specific gravity may rise, under ordinary circumstances, about 2°.[2] The average specific gravity of unskimmed milk may be taken as 1030 at 60° Fahr., and the range is nearly 4° above and below the mean. It varies with temperature, so that in the tropics the medical officer will have to allow for this difference. The following are the relative degrees of a milk that shows 1030 at 60° Fahr., and 1031 at 39° Fahr. (maximum density-point of water):—

Temperature of Milk,	39° F. = 1031	Temperature of Milk,	80° F. = 1027·5
,, ,,	60° F. = 1030	,, ,,	90° F. = 1025·8
,, ,,	70° F. = 1029	,, ,,	100° F. = 1024·0

The addition of water may be detected by the specific gravity. At 60°

[1] Figures of the microscopical appearances are given in some very good papers on the subject in the *British Medical Journal*, Oct. 1869.

[2] Dr Davies records a case where the specific gravity was 1024·6; there was 17 per cent. of cream, and the solids were 16·25. A case of this kind cannot mislead if the amount of cream is determined. Davies recommends that the specific gravity of the whey should be taken; he says it is very constant between 1026 and 1028.

In one sample I examined the specific gravity was 1020, and the cream $\frac{12}{100}$; the specific gravity of the skimmed milk was 1028·9. Another sample gave specific gravity 1017·6, cream $\frac{12}{100}$; specific gravity of skimmed milk, 1032·75. Another sample (which purported to be the same as the last) gave a specific gravity of 1018·84, but the cream was only $\frac{4}{100}$; in this case the greater part of the cream had been removed, and about 50 per cent. of water added.—(F. de C.)

Fahr., there is a loss of 3° for every 10 per cent. of water added. No doubt the method is not perfect, but its ease of application strongly recommends it.

4. *Examine chemically for the Amount of the Different Constituents.*

(*a*) *Total solids.*—Evaporate a known quantity to dryness in a flat and shallow dish, and weigh. Calculate the percentage. The heat must not exceed 212° Fahr. (100° C.), and should be continued for at least three hours. There should be no charring.

(*b*) *Ash.*—Incinerate the dried solids, and weigh.

(*c*) Determine the amount of *fat*. This is best done by means of the fat apparatus of Gerber or of Soxhlets, in which ether or petroleum ether is made to pass repeatedly through the solids of milk, dried after being mixed with plaster of Paris, or soaked up by bibulous paper (Adams' method).[1] The solids dried alone are inconvenient, as they become horny in consistence, and are thus acted upon with difficulty by the ether. The ether carries down with it the fat. The ether is then evaporated and the fat weighed. Should the milk have become sour, Adams recommends the addition of ammonia, which restores the fluidity without otherwise affecting the constituents. An approximate result can be given by the employment of an instrument called a lactoscope, which measures the degree of transparency. The lactoscope of Donné has been improved by Vogel, as a simple plan for ascertaining the amount of fat in milk.[2]

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[1] See *Analyst*, March 1885.

[2] Vogel's instrument consists of a little cup, formed by two parallel pieces of glass, distant $\frac{1}{2}$ a centimetre (=0·1968 inches, say $\frac{2}{10}$ths of an inch) from each other, and closed everywhere except at the top, so as to form a little vessel; a glass graduated to 100 c.c., and a little pipette, which is divided to $\frac{1}{2}$ c.c., are also required. Water (100 c.c.) is placed in the measure, and 2 or 3 c.c. of milk (which should be at first agitated, so as to mix any separate cream) are added to it. The parallel glass cup is then filled with this diluted milk, and a candle placed about one metre from the eye (=39·37 inches) is looked at in a rather darkened room; if the flame of the candle is seen, the milk is poured back into the large measure; more milk is added to it, and it is poured again into the parallel glass, and the light is again looked at; the experiment ends when the contour of the light is completely obscured. The candle should be a good one, but the difference in the amount of light is not material. The percentage amount of fat in the milk is then calculated by the following formula (which has been determined by a comparison of the results of the instrument, and of chemical analysis): x being the quantity of fat sought, and m the number of c.c. of milk which added to the 100 c.c. of water suffice to obscure the light.

$$x=\frac{23\cdot2}{m}+0\cdot23.$$

If, for example, 3 c.c. of milk, added to 100 of water, were sufficient to obscure the light, the percentage of fat is—

$$x=\frac{23\cdot2}{3}+\cdot23=7\cdot96 \text{ per cent.}$$

From this formula the following table has been calculated, which enables us to read off at once the percentage of fat:—

C.c. Milk.	=	Per cent. of Fat in the Milk.	C.c. Milk.	=	Per cent. of Fat in the Milk.
1	to 100 of water obscures the light=	23·43	7·5	to 100 of water obscures the light=	3·32
1·5	,, ,,	15·69	8	,, ,,	3·13
2	,, ,,	11·83	8·5	,, ,,	2·96
2·5	,, ,,	9·51	9	,, ,,	2·80
3	,, ,,	7·96	9·5	,, ,,	2·67
3·5	,, ,,	6·86	10	,, ,,	2·55
4	,, ,,	6·03	11	,, ,,	2·43
4·5	,, ,,	5·38	12	,, ,,	2·16
5	,, ,,	4·87	13	,, ,,	2·01
5·5	,, ,,	4·45	14	,, ,,	1·88
6	,, ,,	4·09	15	,, ,,	1·78
6·5	,, ,,	3·80	16	,, ,,	1·68
7	,, ,,	3·54	17	,, ,,	1·60

(*d*) *Casein.*—Take a weighed or measured quantity; add two or three drops of acetic acid, and boil. Add a good deal of water; allow to stand for twenty-four hours; pour off the supernatant fluid; wash the precipitate well with ether at 80°; dry, and weigh. Calculate the percentage. It is difficult to free it entirely from fat. Wanklyn recommends the albuminoid ammonia process, as in the case of nitrogenous matter in water, 1 part of casein yielding 0·065 of ammonia. The determination is not often required.

(*e*) Determine the amount of *lactin* by the saccharometer, or by the standard copper solution.[1] To do this, take 10 c.c. of milk, add a few drops of acetic acid, and warm—this coagulates the casein with the fat; then make up to 100 c.c. with distilled water, filter, and put the filtered whey (which ought to be as clear as possible) into a burette. Take 10 c.c. of standard copper solution, put it in a porcelain dish, and add 20 or 30 c.c. of distilled water; boil; as soon as it is in brisk ebullition drop in the whey from the burette; take care that the liquid is boiling all the time; continue the process until the copper is all reduced to red suboxide and no blue colour remains in the supernatant liquid; but stop before any yellow colour appears. Read off the amount of whey used, and divide by 10; the result is the amount of milk which exactly decomposes 10 c.c. of the copper solution. The 10 c.c. of the copper solution are equal to 0·0667 gramme of lactin. The amount of lactin in the 10 c.c. of milk is then known by a simple rule of three; and the amount in 100 c.c. of milk is at once obtained by shifting the decimal point one figure to the right.

Example.—15 c.c. of diluted whey were required to reduce the 10 c.c. of copper solution; $\frac{15}{10} = 1{\cdot}5$ the amount of original milk; $0{\cdot}0667 \div 1{\cdot}5 = 0{\cdot}0445$ gramme of lactin in 1 c.c.; therefore $0{\cdot}0445 \times 100 = 4{\cdot}45$ per cent.

5. *Examine the Milk microscopically.*—The only constituents of milk are the round oil globules of various sizes in an envelope and a little epithelium. The abnormal constituents are epithelium in large amount, pus, conglomerate masses, and casts of the lacteal tubules. The added ingredients may be starch grains, portions of seeds, and chalk (round and often highly refracting bodies, with often a marked double outline, and at once disappearing in acid). Colostrum, occurring for three to eight days after the birth of the calf, is composed of agglomerations of fat vesicles united by a granular matter.

C.c. Milk.	=	Per cent. of Fat in the Milk.	C.c. Milk.	=	Per cent. of Fat in the Milk.
18	to 100 of water obscures the light=	1·52	40	to 100 of water obscures the light=	0·81
19	,, ,,	1·45	45	,, ,,	0·74
20	,, ,,	1·39	50	,, ,,	0·69
22	,, ,,	1·28	55	,, ,,	0·64
24	,, ,,	1·19	60	,, ,,	0·61
26	,, ,,	1·12	70	,, ,,	0·56
28	,, ,,	1·06	80	,, ,,	0·52
30	,, ,,	1·00	90	,, ,,	0·49
35	,, ,,	0·89	100	,, ,,	0·46

If, for example, 1 cubic centimetre of milk to 100 of water obscures the light, the percentage of fat is 23·43; if 8 cubic centimetres, added to 100 of water, are needed to obscure the light, the percentage is 3·13, &c.; so that in four or five minutes an approximate analysis of the milk is made, as far as the fat is concerned.

Wanklyn states that 0·2 gramme of fat equals 1 gramme of cream.

[1] See Appendix A. Wanklyn recommends dissolving out the lactin from the solids (after the fat is removed) by means of alcohol, evaporating and weighing; then incinerating; the difference gives the amount of lactin. This seems on the whole less convenient for the medical officer than the copper test. Macnamara (*Indian Medical Gazette*, 1873) uses alcohol for extracting the lactin, but determines it by Fehling's copper test.

Infusoria are sometimes found in milk, and *fungi* (*Oïdium lactis* and *Penicillium*) are so almost invariably, if the milk has been kept.[1]

Scheme for a Short Examination.

As a medical officer is constantly called upon to examine milk, and will seldom have time to go thoroughly into all the points just noted, the following short scheme will be useful :—

1. Put some milk into the long graduated glass for deposit, and for determining percentage of cream.[2]

2. Take physical characters, reaction, and specific gravity. Take specific gravity of the whey, if there be time to do this.

3. Determine fat by Vogel's milk-test.[2] Other plans of examination are recommended, such as the Lactobutyrometer of Marchand, and the Lactocrite, but those apparatus are not likely to be in the hands of medical officers.

4. Examine the milk with the microscope. The comparison of the specific gravity, and the amount of cream which rises, or of fat, will be found to give, in conjunction with the physical characters, a very good idea of the quality of the milk.

ADULTERATIONS.

1. *Water.*—This is extremely common, and is, in fact, generally the only adulteration; it is best detected by specific gravity or by the amount of solids by evaporation. Wanklyn suggests the amount of ash as a good test of watering; the normal ash being, according to him, about 0·73 per cent. In this case the calculation would be as follows :—Let (a) be the observed percentage of ash and (A) the normal amount: then $100 - \frac{100a}{A} =$ per cent. of water added: let (a) $= 0·50$, and $A = 0·73$: then $100 - \frac{100 \times 0·50}{0·73} = 31·5$ per cent. of water added. In a similar way the amount of "solids not fat" may be used as a standard.

2. *Starch, dextrin, or gum*, to conceal the thinness and the bluish colour produced by water. Not a common adulteration. Add iodine at once for starch; boil with a drop of acetic acid, and add iodine for dextrin, or add acetate of lead and then ammonia: a white precipitate falls.

3. *Annatto* or *turmeric* is added to give colour. Liquor potassæ at once detects turmeric.

4. *Emulsions* of seeds (*hemp* or *almond*), added; this is uncommon. Boil. The albumen of the seeds coagulate; the milk will not mix with tea. Hemp seed gives an unpleasant odour to the milk (Normandy).

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[1] Dr Willard, of Cornell University, notes the experience of Professor Law, who observed a peculiar ropy material in milk, and traced it to cows drinking stagnant water containing organisms similar to those found in the milk; a drop of this water, put into good milk, soon developed these organisms. The cows were feverish.—(Dr John Ogle, *Journal of the Agricultural Society*, Nov. 15, 1872; *Lancet*, Oct. 11, 1873.)

[2] Macnamara (*Indian Medical Gazette*, 1873) finds that the cream is not very useful in India as a test, the rapid coagulation of the milk preventing it rising. The addition of ammonia, as recommended by Adams, might obviate this. Similarly Vogel's test does not give satisfactory results. It would, therefore, be necessary to determine the constituents by the chemical methods if possible. The following plan may be adopted :—Measure out carefully two portions of milk, and evaporate both to dryness: weigh: from this the *total solids* may be obtained: then incinerate one portion: weigh: this gives the *ash*. Exhaust the other with ether in Gerber's or Soxhlet's apparatus: from this the *fat* may be obtained. (The sample dried for fat had better be mixed with plaster, or soaked up with bibulous paper in Adams' way.) Exhaust the residue with alcohol; this gives the *lactin*, which may be determined either by weighing or incineration, or by Fehling's process; weigh the residue, then incinerate it, and weigh again: the difference will be the *casein*. The last weighing also gives a controlling determination of the ash.

5. *Glycerin* has been sometimes met with. The milk will be sweeter than usual, and there will be a difficulty if not impossibility in drying the solids by evaporation.

6. *Chalk*, to neutralise acid, and to give thickness and colour. Let it stand for deposit; collect and wash deposit, and add acetic acid and water; after effervescence, filter, and test with oxalate of ammonium.

7. *Sodium Carbonate.*—Very difficult of detection unless the milk be alkaline. Determine the ash, and see if it effervesces; if so, either some carbonate has been added, or, if the sodium have united with lactic acid, this will be converted into carbonate, and enough lactic acid to give an effervescing ash does not exist in good milk.

8. *Salt* has been found added to milk in a case at Glasgow, to the extent of 0·14 to 0·21 per cent., equal to 98 and 147 grains per gallon. This will be detected by the excess of ash which may be dissolved and the chlorine determined in the usual way.

9. Milk is often *boiled* to preserve it; it may then take up from the vessel lead, copper, or zinc, if these metals are used.

10. *Cream* is adulterated or made with magnesium carbonate, tragacanth, and arrowroot. The microscope detects the latter, and particles of magnesium carbonate (round) can also be seen, and found to disappear with a drop of acid. It is also said that yolk of egg is added both to cream and milk.[1]

11. In most cases of falsification milk is *watered* or *creamed*, or both *creamed* and *watered*. *Watering* alone is detected by a lowered specific gravity and a diminished quantity of cream. *Creaming* alone is detected by a heightened specific gravity and a diminished quantity of cream. When both are resorted to, the cream will be small in amount, but the specific gravity may be normal. When a quantitative analysis can be made, watering alone is indicated by a general lowering of the constituents, which, however, preserve their normal proportions to each other. Creaming alone is indicated by a lessened amount of fat, but a normal amount of everything else, except total solids. Creaming and watering may be known by a general lowering of all constituents, but the deficiency in fat will be most marked.

SECTION V.

BEVERAGES.

Sub-Section I.

EXAMINATION OF BEER.

This is directed to ascertain—1. Quality; 2. Adulterations.

1. *Quality.*

Physical Characters.—The beer should be transparent, not turbid. Turbidity arises from imperfect brewing or clarifying, or from commencing changes. If the latter, the acidity will probably be found to be increased. The amount of carbon dioxide disengaged should neither be excessive nor deficient.

The taste should be pleasant. If bitter, the bitterness should not be persistent. It should not taste too acid.

Smell gives no indication till the changes have gone on to some extent.

[1] Mr Bottle, *Pharmaceutical Journal*, February 1873.

If there is any turbidity, microscopic examination will detect the presence of abnormal organisms, as figured by Pasteur.[1]

2. *Determine Specific Gravity.*—Do this both before and after driving off the alcohol. If it is done after the alcohol is driven off, an approximate conclusion can be formed of the amount of solids by dividing by 4 the excess of the specific gravity over 1000. The more extract, the greater is the body of the beer.

3. *Determine Acidity.*—This is a very important matter, as the increase of acidity is an early effect when beer is undergoing changes.

The acidity of the beer consists of two kinds.

Volatile acids, viz., acetic and carbonic.

Non-volatile acids, viz., lactic, gallic or tannic, malic, and sulphuric, if it has been added as an adulteration.

To determine the acidity of beer we must use an alkaline solution of known strength, 1 c.c. of which is equal to 6 milligrammes of glacial acetic acid ($C_2H_4O_2$) or to 9 milligrammes of lactic acid ($C_3H_6O_3$).[2]

Take 10 c.c. of the beer to be examined, and drop into it the alkaline solution from a burette, till exact neutrality (as tested by turmeric and litmus papers) is reached. Then read off the number of c.c. of alkaline solution used; multiply by 6, and the result will be the amount of total acidity in the quantity of beer operated on, expressed as milligrammes of glacial acetic acid (the symbols being always used in the report). By shifting the decimal point two places to the right, the amount per litre is given. To bring grammes per litre into grains per pint multiply by 70 and divide by 8; or, what is the same thing, multiply at once the number of c.c. of alkaline solution used by 5·25 (short factor).

The total acidity can be divided into fixed and volatile by evaporation. While the total acidity is being determined, evaporate another measured quantity of beer to one-third, make up to the original bulk with distilled water, and determine the acidity. The acetic and carbonic acids being volatile are driven off, and lactic and other acids remain. Deduct the amount of alkaline solution used in this second process from the total amount used, and this will give the amount used for the volatile and fixed acidities respectively; express one in terms of acetic, the other of lactic acid. Short factor for lactic acid = 7·875. The fixed acidity is greater than the volatile in almost all beers, and sometimes five or six times as much.

Example.—10 c.c. of beer took 5 c.c. of alkaline solution: $5 \times 5{\cdot}25 = 26{\cdot}25$ grains of glacial acetic acid per pint = total acidity.

After boiling and making up to original bulk with distilled water, 10 c.c. took 4 c.c. of alkaline solution: $4 \times 7{\cdot}875 = 31{\cdot}5$ grains of lactic acid per pint = fixed acidity. The difference between the amounts of alkaline solution used, $5 - 4 = 1$ multiplied by 5·25, gives the volatile acidity.

Generally speaking, the amount of total acidity of beer given in books is too great. It is seldom found to be more than 30 grains per pint, and even rarely reaches that; sometimes it is not more than 14 or 15 grains. In thirty-one kinds of porter and stout the acidity per pint varied from 25·22 grains (the highest) to 14·14 grains (the lowest amount). In twenty-three kinds of ale the highest and the lowest amounts per pint were 34·39 and 7·97 grains.[3]

4. *Determine Amount of Alcohol.*—There are various ways of doing this, but one of the two following will be sufficient.

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[1] *Etudes sur la Bière*, 1876, plate i. p. 6.
[2] See Appendix A.
[3] *British Medical Journal*, June 1870.

Measure a certain quantity, say one pint of beer, and take the specific gravity at 60° or 68° Fahr.[1] 1*st*, Put into a retort and distil at least two-thirds. Take the distillate, dilute to original volume with distilled water, determine the specific gravity at 60° or 68° by a proper instrument, and then refer to the annexed table of specific gravities—opposite the found specific gravity the percentage of alcohol is given in *volume* (not in *weight*).

2*nd*, Then, to check this, a plan recommended by Mulder may be used. Take the residue of the beer in the retort, dilute with water to the original volume, and take the specific gravity at 60° or 68°.

Then deduct the specific gravity before the evaporation from the specific gravity after it, take the difference, and deduct this from 1000 (the specific gravity of water), and look in the table of specific gravities for the number thus obtained; opposite will be found the percentage of alcohol. The results of these two methods should be identical.

If there is no retort, this second plan may be used with a common evaporating dish, the alcohol being suffered to escape. A common urinometer (tested for correctness in the first place by immersion in distilled water at 62° Fahr.) may be employed for determining the specific gravity. The plan is very useful for medical officers; it requires nothing but a urinometer and evaporating dish, with reasonable care and slowness of evaporation, so as not to char the residue and render it insoluble.

Alcohol (Volume) according to Specific Gravity.

100 parts.		Specific Gravity.		100 parts.		Specific Gravity.	
Alcohol.	Water.	At 68°.	At 60°.	Alcohol.	Water.	At 68°.	At 60°.
50	50	0·914	0·917	24	76	0·966	0·968
49	51	0·917	0·920	23	77	0·968	0·970
48	52	0·919	0·922	22	78	0·970	0·972
47	53	0·921	0·924	21	79	0·971	0·973
46	54	0·923	0·926	20	80	0·973	0·974
45	55	0·925	0·928	19	81	0·974	0·975
44	56	0·927	0·930	18	82	0·976	0·977
43	57	0·930	0·933	17	83	0·977	0·978
42	58	0·932	0·935	16	84	0·978	0·979
41	59	0·934	0·937	15	85	0·980	0·981
40	60	0·936	0·939	14	86	0·981	0·982
39	61	0·938	0·941	13	87	0·983	0·984
38	62	0·940	0·943	12	88	0·985	0·986
37	63	0·942	0·945	11	89	0·986	0·987
36	64	0·944	0·947	10	90	0·987	0·988
35	65	0·946	0·949	9	91	0·988	0·989
34	66	0·948	0·951	8	92	0·989	0·990
33	67	0·950	0·953	7	93	0·990	0·991
32	68	0·952	0·955	6	94	0·992	0·992
31	69	0·954	0·957	5	95	0·994	0·994
30	70	0·956	0·958	4	96	0·995	0·995
29	71	0·957	0·960	3	97	0·997	0·997
28	72	0·959	0·962	2	98	0·998	0·998
27	73	0·961	0·963	1	99	0·999	0·999
26	74	0·963	0·965	0	100	1·000	1·000
25	75	0·965	0·967				

Alcohol is sometimes stated as *weight in volume*. The following table shows tolerably accurately the relation between the two and the relative

[1] Hassall recommends previous removal of CO_2, by shaking up in a corked bottle for ten minutes, opening the bottle from time to time, and sucking air through it with a tube. This is more necessary with bottled than draught beer.

amount of proof-spirit, so that a little calculation will reduce one table into another if desired. In other words, if the percentage of alcohol in *volume* be multiplied by 0·8, the *weight* of the alcohol is given per cent. If the percentage of alcohol in *weight* is multiplied by 1·25, the *volume* is given. If the percentage *volume* of alcohol be multiplied by 1·76, the amount of *proof-spirit* is given.[1]

Per cent. in Volume.	Per cent in Weight.	Proof Spirit.
1	0·8	1·76
2	1·6	3·54
3	2·4	5·35
4	3·2	7·00
5	4·0	8·80
6	4·8	10·56
7	5·6	12·32
8	6·4	14·00
9	7·2	15·76
10	8·0	17·60

5. The *solids* can be determined by evaporation, and the *ash* obtained by incineration; but medical officers will seldom have occasion to do this. The specific gravity of the de-alcoholised beer gives a sufficient approximation.

6. Evaporate the beer to a syrupy consistence; it should have a pleasant bitter taste.

The points, then, to be determined in judging of quality are—1, taste; 2, appearance; 3, microscopic characters; 4, specific gravity of de-alcoholised beer, from which we find the per cent. of extract; 5, acidity; 6, amount of alcohol; 7, taste of syrupy extract.

2. *Adulterations of Beer.*[2]

1. *Water.*—Probably the most frequent adulteration; detected by taste; determining amount of alcohol and specific gravity of the beer free from alcohol.

2. *Alcohol.*—Seldom added; the quantity of alcohol is large in proportion to the amount of extract, as determined by the specific gravity after separation of the alcohol.

3. *Sodium* or *Calcium Carbonate in order to lessen Acidity.*—Neither adulteration can be detected without a chemical examination. Evaporate beer to a thick extract, then put in a retort, acidulate with sulphuric acid, and distil; if calcium or sodium acetate be present, acetic acid in large quantity will pass over. The extract always contains some acetate, but only in small quantity.

Lime.—Evaporate to dryness another portion of beer, incinerate, dissolve in weak acetic acid, and precipitate by ammonium oxalate. In unadulterated beer the precipitate is moderate only.

Excess of soda, for some always exists in beer, is detected with much greater difficulty, and it will be well not to attempt this. Mulder states that the presence of too great a quantity of lactates may be determined by

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[1] For method of testing by Sikes' hydrometer, see Appendix.

[2] In his speech in the House of Lords (April 17, 1872, *Times'* report), Lord Kimberley stated that a common adulteration is as follows:—A certain amount of beer is drawn from the cask of 84 gallons, and then 6 lb of "foots" (a black coarse sugar), 1½ gallon of "finings" (made from skins of soles and other fish), and 12 gallons of water are put in per cask. This beer is ready for sale in two hours, and must be drunk in two days or it goes bad. Salt and copperas are added by some, but the use of copperas is said not to be general. Ale and stout are not mixed with water, but "finings" are used.

boiling the beer with zinc carbonate, when lactate of zinc deposits.[1] In these cases the beer has begun to change, and the microscope and reference to Pasteur's plate will greatly assist.

4. *Sodium chloride.*—This is hardly an adulteration, unless a very large quantity is added.[2] Take a measured quantity of the beer; evaporate to dryness; incinerate at as low a heat as possible; dissolve in water, and determine the chloride by the standard solution of nitrate of silver.

5. *Ferrous Sulphate.*—If the beer be light-coloured a mixture of potassium ferricyanide and ferrocyanide (Faraday's test) may be added at once, and will give a precipitate of Prussian blue; if the beer be very dark-coloured, it must be decolorised by adding solution of lead subacetate and filtering.

Or evaporate a portion of beer to dryness and incinerate; if any iron be present the ash is red; dissolve in weak nitric acid, and test with potassium ferrocyanide. Two grains of ferrous sulphate to nine gallons of water give a red ash (Hassall). The ash of genuine porter is always white, or greyish white (Hassall).

6. *Sulphuric acid* is added to clarify beer, and to give it the hard flavour of age. If the beer be pale, add a few drops of hydrochloric acid, and test with barium chloride. A *very dense* precipitate may show that sulphuric acid has been added, but it must be remembered that the water used in brewing may contain large quantities of sulphates. (The Burton spring water is rich in calcium sulphate.) If there be a *large* precipitate, then determine the acidity of the beer before and after evaporation; if the amount of fixed acid be found to be *very* large, there will be no doubt that sulphuric acid has been added; or precipitate with baryta, and weigh.

Mulder recommends that the extract of the beer be heated, and the sulphur dioxide which is disengaged led into chlorine water; sulphuric acid will be found in the chlorine water, and may be tested for as usual.

7. *Alum.*—Evaporate to dryness; incinerate, and proceed exactly as in the analysis of alum in BREAD. The substance added to give "head" to beer is a mixture of alum, salt, and ferrous sulphate.

8. *Burnt Sugar—Essentia bina—Foots.*—Evaporate the beer to an extract; dissolve in alcohol; evaporate again to extract, and taste. According to Pappenheim, these substances prevent the regressive metamorphosis of the tissues, and thus injure health. Burnt sugar is added to porter to give colour, and the addition is not illegal.

9. *Capsicum—Peppers—Grains of Paradise.*—Evaporate to dryness carefully; dissolve in alcohol; filter; evaporate very carefully to dryness, and taste if there is any pungency. In fourteen out of twenty samples of illicit beer, Mr Phillips found that grains of paradise had been added. It is said that the oils of pimento, zedoary, and ginger are sometimes used.

10. *Aloes.*—The taste alone is not reliable. Dr Koehler[3] proposes to evaporate the beer. Dissolve the residue in nitric acid, when a yellowish-red liquid is obtained, which takes a deep blood-red colour when treated with liq. potassæ and glucose, or with liq. potassæ and either cyanide of potassium or sulphide of ammonium, if aloe-resin is present. The nitric acid solution is not decolorised by stannous chloride; if hops only have been used, it is decolorised.

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[1] *De la Bière* (French edition), 1861, p. 258.
[2] The Inland Revenue Office allows 50 grains of sodium chloride per gallon.
[3] Schmidt's *Jahrb.*, 1871, No. 10, p. 22.

11. *Colocynth.*—The residue of evaporated beer, heated with nitric acid, yields a yellow solution; with concentrated sulphuric acid, an intense red solution; and a cherry-red colour is given with Froehde's test (molybdate of sodium dissolved in sulphuric acid).[1]

12. *Colchicin.*—A case is recorded by Dr Böttern [2] of Faaborg, in Norway, where colchicin was detected in some English beer, and caused symptoms of poisoning (vomiting, diarrhœa, burning pain in the head, stomach, &c.).

13. *Santonin.*—Evaporate beer to extract; treat with alcohol, filter, evaporate, and prepare the santonin as usual by boiling with lime, and precipitating by an acid.

14. *Cocculus indicus.*—It is not known whether much of this is now used. The witnesses examined in 1856 by the Committee of the House of Commons (Scholefield's) all doubted it; a large quantity of *Cocculus indicus* is, however, annually imported, and no other use is known.[3] In two instances out of twenty specimens of adulterated beer, analysed in 1863 by Mr Phillips, *Cocculus indicus* was found in large quantities.

For the detection of *Picrotoxine*, Herapath recommends that the beer be first treated with lead acetate; filtered; excess of lead got rid of by hydrogen sulphide; fluid evaporated to a small bulk, and mixed with animal charcoal. The charcoal absorbs the picrotoxine; it is boiled in alcohol, and the alcohol is evaporated on slips of glass. The picrotoxine crystallises as plumose tufts of circular or oat-shaped crystals.

Dr Langley, of Michigan,[4] recommends acidulating the beer with hydrochloric acid and agitating with ether; the etherial solution yields on evaporation crystals of picrotoxine.

A plan devised by Depaire is considered by Koehler as one of the easiest and at the same time the best. Mix one litre of beer with finely powdered rock salt: resinous and extractive matters are thrown down. Shake the liquid with ether; an impure picrotoxine is obtained, which can be purified.

None of these processes will give more than $\frac{4}{10}$ths of the picrotoxine.

When the crystals of picrotoxine are obtained, test them as follows:—

(*a*) Rub the crystals with 3 or 4 parts of pure nitrate of potassium; add 1 or 2 drops of strong sulphuric acid, and then an excess of strong solution of soda or potash. A bright reddish-yellow colour is given if picrotoxine be present (Langley).

(*b*) Dissolve the crystals in strong sulphuric acid; a yellow fluid is obtained. Stir it with a glass rod which has been dipped in a concentrated solution of potassium bichromate; a bluish-violet colour is obtained (like a strychnine reaction), which changes soon into brown, brown-green, and at last apple green.

(*c*) If a good deal of picrotoxine is obtained, dissolve it in water, and put a small fish in the water; the poisonous effects occur in a short time.

15. *Strychnine* or *Nux Vomica.*—This is a very uncommon adulteration, if it ever occur. Add animal charcoal to the beer; digest for twenty-four hours; pour off beer; boil the charcoal in alcohol; filter; evaporate one-half; add a few drops of liquor potassæ and then ether; agitate; pour off ether, and evaporate to dryness; test for strychnine by the colour test (sulphuric acid and potassium bichromate, or peroxide of lead, or manganese, or potassium permanganate).[5]

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1 Koehler, *op. cit.*
2 *Med. Times and Gazette*, May 16, 1874, p. 29.
3 It is said to be obtainable from wholesale druggists under the name of *multum*.
4 *Chemical News*, Sept. 6, 1862.
5 Other vegetable bitters are used, but their detection is difficult and uncertain. Mr Sorby recommends the spectroscope for detecting calumba root.

16. *Tobacco* is occasionally used; in twenty specimens of illicit beer examined in 1863, by Mr Phillips of the Inland Revenue Department, tobacco was found in one.

17. *Picric (Trinitrophenic) Acid.*—Lassaigne recommends the addition of subacetate of lead and animal charcoal; if the beer has still a yellow colour, picric acid is present. But, as Mulder and Hassall observe, many beers destitute of picric acid remain yellow. Pohl advises to add white uncombed wool; if picric acid be present, it stains it. This is an uncertain test. H. Brunner extracts the picric acid from the wool with hot aqueous ammonia; concentrates to a small bulk, and tests with a drop of solution of cyanide of potassium. A red coloration of isopurpurate of potassium will be produced if there be 1 part of picric acid in 500,000 of water (Hassall).

18. *Copper.*—Evaporate a portion of the beer to dryness; incinerate; dissolve in weak nitric acid; test for copper by the insertion of a clean knife; by addition of ammonia and of potassium ferrocyanide.

19. *Lead.*—Evaporate a considerable quantity of the beer to dryness; incinerate; dissolve in weak nitric acid, and test for lead as usual.

SUB-SECTION II.

EXAMINATION OF WINE.

The quality of wine can be best determined by noting the colour, transparency, and taste, and then determining the following points:—

(1) The amount of *solids* as given by the specific gravity after the elimination of the alcohol. In the best Clarets, before the loss of alcohol, the specific gravity is very nearly that of water. In some Claret used in the Queen's establishment, and analysed by Dr Hofmann, the specific gravity was ·99952. In other Clarets it is as low as ·995. A low specific gravity shows that alcohol has been added, or that the solids are in small amount.

(2) The amount of *alcohol;* a very small amount may show the addition of water, a large amount the addition of spirits.

(3) The amount of *free acidity.* This is an important point, as it seems clear that some persons (especially the sick) do not readily digest a large amount of acid and acid salts.

The amount is determined by the alkaline solution. The free acidity is generally reckoned as crystallised tartaric acid ($C_4H_6O_6$), 1 c.c. of the alkaline solution being equal to 7·5 milligrammes. There is both fixed and volatile acidity; the relative amount of the two is difficult to determine satisfactorily, as some acid may be formed on distillation. The distillation should be conducted at a low temperature, so as not to decompose the fixed compound ethers. The volatile acidity is reckoned as glacial acetic, the fixed as tartaric acid. All the acidities of wine are usually reckoned as grains per *ounce.*

The amount of free acidity varies greatly even in the same kind of wines; the least acid wines are Sherry, Port, Champagne, the best Claret and Madeira; the more acid wines are Burgundy, Rhine wine, Moselle (Bence Jones). The amount of free acid in good Clarets is equal to 2 to 4 grains of tartaric acid per ounce; in common Clarets and in Beaujolais it may be 4 to 6 grains, and in some extremely acid wines it may be even more than this. In the best Champagnes it is 2 to 3 grains usually; but it has been known to reach in excellent Champagne 1·12 per cent., or 4·8 grains per ounce.[1] In Port it averages 2 to 2½ grains, but may reach 4 grains; in Sherry, 1½ to 2¼ grains;

[1] This was the case in some Champagne examined by Dr Hofmann.

in the Rhine wines, $3\frac{1}{2}$ to 4 or 6 grains. Thudichum and Dupré state that in good sound wine the amount of free acidity ranges from 0·3 to 0·7 per cent., or from 1·3 to 3 grains per ounce.

The taste of wine does not depend entirely on, but yet is very greatly influenced by, the degree of acidity. Mr Griffin[1] states that good-tasted wine contains from 1·87 to 2·8 grains of crystallised tartaric acid per ounce; that if it contains less than 1·87 grains it tastes flat; if more than 3 grains per ounce the wine is too acid to be agreeable; if more than 4·37 grains per ounce (1 per cent.) it is too acid to be drunk. These numbers seem rather low.[2]

(4) The amount of *sugar*. The best modes of determining this have been already noticed.

(5) It may be sometimes useful to determine the amount and kind of *ethers* by fractional distillation.

Excessive acidity of wine can be corrected by adding neutral potassium tartrate. Milk is also often used. The addition of the carbonated alkalies, or of chalk, alters the bouquet of the wine. When wine becomes stringy, in which case acetic and lactic acids are formed, it may be improved by adding a little tea; about one ounce of tea boiled in 2 quarts of water should be added to about 40 gallons of wine. Bitter wine is treated with hard water or sulphur; bad smelling wine with charcoal; too astringent wine with gelatin; wine which tastes of the cask with olive oil.[3]

Adulterations of Wine.

1. *Water.*—Known by taste; amount of alcohol; specific gravity after elimination of alcohol.

2. *Distilled Spirits.*—Known by determining the amount of alcohol, the normal percentage of the particular kind of wine being known. By fractional distillations the peculiar-smelling fusel oils may be obtained; or merely rubbing some of the wine on the hand, and letting it evaporate, may enable the smell of these ethers to be perceived.

3. *Artificial Colouring Matters.*—The following are the chief colouring matters, as stated by Thudichum and Dupré. Logwood is the great colouring material, and also blackberries, elderberries, and bilberries. There are no good methods of recognising these substances; salts of lead, ammonia, and ammonium sulphide, alum, and potassium or ammonium carbonate, and salts of tin have been used as reagents. The most useful test appears to be this: add to the wine about $\frac{1}{4}$th volume of strong solution of alum; stir well, and then add about an equal quantity of strong solution of ammonium carbonate; the natural colouring matter of the wine when thrown down in this way has a greenish or dirty bluish-green colour, but there is no tinge of red; logwood and several other abnormal colours have a distinct red or purplish tint.[4] The use of strips of gelatin, as described under Alum in BREAD, is

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[1] *Report on Cheap Wine*, by R. Druitt, M.D., p. 178.

[2] From thirteen analyses of sound ordinary Port, I found the mean acidity to be 1·97 per ounce; in some samples of Sherry, 1·90; Marsala, 1·5; light Claret, 3·1; in a rather sour Claret, 4·0; in a sample of Montilla, a fine wine, but too acid, 3·15.—(F. de C.)

[3] Wine is subject to several diseases, which, according to Pasteur, depend on different kinds of ferments (see Review on Hygiene, in *Army Medical Department Report*, vol. vii. p. 340). By heating the wine to about 125°–130° Fahr. these "mycoderms" are killed, and the wine undergoes no further change. The microscope may be employed, as in the case of beer.

[4] Mulder speaks very doubtfully of all such tests; they seem, however, better than nothing. Probably spectrum analysis will hereafter afford the best means of identification. On the colouring matter of wine, see Duclaux, *Comptes Rendus de l'Académie des Sciences*, t. lxxvii., No. 16, April 1874, p. 1159; also Report on Hygiene, *Army Med. Reports*, vol. xv., p. 190.

also recommended. Fuchsine or rosaniline and other substances have also been used, but on the whole there has been some exaggeration, whilst the colouring matters employed are mostly harmless.

4. *Lime Salts.*—The so-called "plâtrage" of wines consists in the addition of $1\frac{1}{2}$ ℔ to 7 ℔ of a mixture of calcium sulphate (80 parts), calcium carbonate (12), quicklime and sulphide and chloride of calcium (8 parts) to 1 hectolitre of wine. Calcium sulphate dissolves in large proportion, and then interchanges with the chloride of potassium, and chloride of calcium and sulphate of potassium are formed. The chalk forms acetate and tartrate of calcium. The proportion of lime salts is then very large. The only precise way of detecting this adulteration is by evaporating to dryness, incinerating, and determining the amount of lime. But the following method is shorter, and will generally answer. The natural lime salts of wine are tartrate and sulphate; when lime is added an acetate of calcium is formed. Evaporate the wine to $\frac{1}{10}$th; add twice the bulk of strong alcohol; the calcium acetate is dissolved, but not the sulphate or tartrate; filter and test with oxalate of ammonium; if a large precipitate occur, lime has probably been added.

5. *Tannin* may be detected either by chloride of iron or by adding gelatin, But as tannin exists naturally in most of the red wines (Port, Beaune, Roussillon, Hermitage, &c.), the question becomes often one of quantity. The amount of tannin can be estimated by drying the tanno-gelatin (100 grains contain 40 of tannin).

6. *Alum.*—This is detected precisely in the same manner as in bread. Evaporate a pint of the wine to dryness; incinerate, and then proceed as directed in BREAD.

7. *Lead.*—Evaporate to dryness, and incinerate; dissolve in dilute nitric acid, and test as directed in the EXAMINATION OF WATER.

8. *Copper.*—Decolorise with animal charcoal, and test at once with ferrocyanide of potassium.

9. *Cider and Perry.*—Evaporate wine, and the peculiar smell of the liquids will be perceived.

Port Wine, as sold in the market, is stated to be a mixture of true Port, Marsala, Bordeaux, and Cape wines with brandy, although at present it is probably purer than it used to be, purer perhaps than most other wines. Inferior kinds are still adulterated with logwood, elderberries, catechu, prune juice, and a little sandalwood and alum. Receipts are given in books for all sorts of imitation wines.

*** The examination of some other articles, viz., Tea, Coffee, Vinegar, Mustard, Pepper, Salt, and Lemon and Lime Juice, will be found under the different heads in BOOK I.

APPENDIX A.

STANDARD SOLUTIONS FOR VOLUMETRIC ANALYSIS.

1. *For Chlorine.*

(*a*) *Silver Nitrate Solution.*

4·788 grammes of silver nitrate in 1 litre of distilled water.
1 c.c. of solution = 1·00 milligramme of chlorine.
,, ,, = 1·65 ,, of sodium chloride.
,, ,, = 2·10 ,, of potassium chloride.
,, ,, = 1·51 ,, of ammonium chloride.

This solution may be *standardised* with a solution of pure sodium chloride, 1·648 to the litre, 1 c.c. of which equals 1 mgm. of chlorine.

(*b*) *Potassium Monochromate Solution.*—50 grammes of potassium monochromate are dissolved in 1 litre of distilled water. Solution of nitrate of silver is added until a permanent red precipitate is formed, which is allowed to settle.

2. *Hardness.*

(*a*) *Soap Solution.*

Dissolve some soft soap (pharmacopœial) in diluted spirit, and graduate by means of this barytic solution.

Nitrate of barium, . . .	0·26 gramme.
Distilled water, ...	1 litre.

2·2 c.c. (or 22 *measures*) of standard soap solution produce a permanent lather with 50 c.c. of the above solution.
1 measure ($=\frac{1}{10}$ c.c.) of soap solution = 0·00025 gm. = 0·25 mgm. of calcium carbonate.
Correction for lather = – 2 measures of soap.
Short factors (when 50 c.c. of water are taken for experiment).

For degrees of Clark's scale (1:70,000) = 0·35.
,, ,, metrical ,, (1:100,000) = 0·50.

(*b*) A weaker solution, each measure ($\frac{1}{10}$ c.c.) of which is equal to 0·07 mgm. of $CaCO_2$ is sometimes used. The correction for lather would be 7 measures of soap. The corrected number of measures, divided by 10, gives the hardness in Clark's scale directly, or multiplied by 0·14, the degrees on the metrical scale.

3. *Solutions required for the determination of Oxidisable Matter in Water.*

(*a*) *Permanganate Solution.*

0·395 of potassium permanganate in 1 litre of water.
100 c.c. are exactly decolorised by 100 c.c. of *oxalic acid solution* (*c*). (*See* No. 10 *c*).
1 c.c. of permanganate solution used with acid yields 0·10 milligramme of oxygen.
1 c.c. of permanganate solution used with alkali yields 0·06 milligramme of oxygen.

1 c.c. of permanganate solution exactly oxidises 0·2875 mgm. nitrous acid (NO_2).

1 c.c. of permanganate solution exactly oxidises 0·2125 mgm. hydrogen sulphide (H_2S).

1 c.c. of permanganate solution exactly oxidises 0·7000 mgm. iron (Fe).

" " " " 0·9000 " ferrous oxide (FeO).

(*b*) *Potassium Iodide Solution.*—A 10 per cent. solution of the pure potassium iodide, recrystallised from alcohol.

(*c*) *Dilute Sulphuric Acid.*—One *volume* of pure sulphuric acid is mixed with three *volumes* of distilled water, and permanganate solution dropped in until the whole retains a *very faint* pink tint after warming to 80° F. for four hours.

(*d*) *Sodium Hyposulphite.*—One gramme of crystallised sodium hyposulphite dissolved in 1 litre of water.

(*e*) *Starch Solution.*—One gramme of starch to be intimately mixed with ½ litre of distilled water, the whole boiled briskly for five minutes, filtered, and allowed to settle.

4. *Solutions for determination of Free and Albuminoid Ammonia.*

(*a*) *Ammonium Chloride Solution for Nesslerising.*

0·315 gramme of ammonium chloride in 1 litre of water.

This is the *strong* solution.

Take 100 c.c. of this solution and dilute to 1 litre.

This is the *standard* solution.

1 c.c. = 0·01 milligramme of ammonia (NH_3) or 0·0082 mgm. of nitrogen.

(*b*) *Nessler's Solution.*—Dissolve 35 grammes of potassium iodide in 100 c.c. of distilled water. Dissolve 17 grammes of mercuric chloride in 300 c.c. of distilled water; warm if necessary, and allow to cool. Add the mercuric solution to the iodide solution until a perceptible permanent precipitate is produced. Then dilute with a 20 per cent. sodium hydrate solution (caustic soda) up to 1000 c.c. (1 litre): add mercuric chloride solution until a permanent precipitate again forms; allow precipitate to settle, and then decant off the clear solution.

(*c*) *Sodium Carbonate* (sometimes required for free ammonia, but not usually needed).—A 20 per cent. solution of recently ignited pure sodium carbonate.

(*d*) *Alkaline Potassium Permanganate Solution* (for Albuminoid Ammonia).—Dissolve 200 grammes of potassium hydrate and 8 grammes of pure potassium permanganate in 1100 c.c. of distilled water, and boil the solution rapidly till concentrated to 1000 c.c.

(*e*) *Distilled Water free from Ammonia.*—The S.P.A. recommend boiling ordinary distilled water with 1 per 1000 of pure ignited sodium carbonate. If the water is distilled with a little phosphoric acid (as recommended by Notter), it comes over quite free. Test with a little Nessler's solution.

5. *Reagents for the determination of Nitric Acid in Nitrates.*

(*a*) *Metallic Aluminum.*—As thin foil.

(*b*) *Solution of Sodium Hydrate.*—Dissolve 100 grammes of solid sodium hydrate in 1 litre of distilled water. When cold, introduce a strip of about 100 square centimetres, say 15 square inches, of aluminum foil previously heated to just short of redness, wrapped round a glass rod; when the aluminum is dissolved, boil the solution briskly in a porcelain basin until about one-third of its volume has evaporated; allow it to cool, and make it up to its original volume with water free from ammonia. The solution must be tested by a blank experiment to prove the absence of nitrates.

(*c*) *Copper Sulphate Solution.*—Dissolve 30 grammes of pure copper sulphate in 1 litre of distilled water.

(*d*) *Metallic Zinc, pure.*—As thin foil. This should be kept in a dry atmosphere, so as to be preserved as far as possible from oxidation.

To make the *wet Copper Zinc couple.*—Put into a flask or bottle a piece of clean zinc foil, and cover it with the copper solution (*c*): allow the foil to remain until it is well covered with a firmly adhering black deposit of copper. (If left too long the deposit may peel off in washing.) Pour off the solution (which may be kept for further use), and wash the conjoined metals with distilled water. The couple is now ready for use. About one square decimetre ($=\frac{1}{6}$ of a square inch) should be used for every 200 c.c. of a water containing 5 parts or under of nitric acid in 100,000. For waters richer in nitrates more will be required.

(*e*) *Standard Solution of Ammonium Chloride* (see 4 (*a*)).

(*f*) *Nessler's Solution* (see 4 (*b*)).

6. *Reagents for the determination of Nitrous Acid in Nitrites.*

(*a*) *Solution of Meta-phenylenediamine.*—Dissolve 5 grammes of meta-phenylenediamine in 1 litre of distilled water, rendered acid with sulphuric acid. Decolorise, if necessary, with animal charcoal.

(*b*) *Dilute Sulphuric Acid.*—One volume of pure sulphuric acid to two volumes of distilled water.

(*c*) *Solution of Potassic Nitrite.*—Dissolve 0·406 gramme of pure silver nitrite in hot water, and decompose it with a slight excess of potassium chloride. After cooling, make the solution up to one litre, allow the chloride of silver to settle, and dilute each 100 c.c. of the clear supernatant liquid again to one litre. 1 c.c. of this diluted solution = 0·01 of a milligramme of NO_2.

The nitrites may also be determined by the permanganate solution (*see* 3).

7. *For determination of Phosphoric Acid.*

One part of pure molybdic acid is dissolved in 4 parts of ammonia, sp. gr. 0·960. This solution, after filtration, is poured, with constant stirring, into 15 parts of nitric acid of 1·20 sp. gr. It should be kept in the dark, and carefully decanted from any precipitate that may form.

8. *Sulphuric Acid Solution for Carbonates in Water.*

Take 4·9 grammes *by weight* of pure H_2SO_4 and dilute to 1 litre.
1 c.c. saturates 5 milligrammes of calcium carbonate.
„ „ 6·2 „ of sodium „

9. *Alkaline Solution for Acidities.*

Take liquor sodæ or liquor potassæ of pharmacopœial strength, and dilute with 8 or 9 parts of distilled water.
Graduate with *oxalic acid solution* (*a*). (*See* No. 7.)

1 c.c. of standard alkaline solution	= 6·3	mgm.	oxalic acid.	
	= 6·0	„	glacial acetic acid.	
	= 9·0	„	lactic	„
	= 7·5	„	tartaric	„
	= 6·4	„	citric	„

10. *Oxalic Acid Solutions.*

Solution (*a*)—Take 6·3 grammes of crystallised oxalic acid, and dissolve in one litre of water.
10 c.c. exactly neutralise 10 c.c. of standard alkaline solution.

Solution (b)—Take 100 c.c. of *solution (a)*, and add 123 c.c. of distilled water; or, dissolve 2·84 grammes of crystallised oxalic acid in 1 litre of distilled water.

This makes the solution for testing the alkalinity of lime or baryta water.

1 c.c. exactly neutralises 1·26 milligramme of lime (CaO).

„ „ „ 3·42 „ of baryta (BaO).

1 c.c. is exactly equivalent to 0·5 c.c. of CO_2 by volume at 32° Fahr. (0° C.).

Solution (c)—Take 100 c.c. of *solution (a)*, and add 700 c.c. of distilled water; or, dissolve 0·7875 gramme of crystallised oxalic acid in 1 litre of distilled water.

This is the solution for graduating the permanganate.

100 c.c. exactly decolorise 100 c.c. of permanganate in presence of sulphuric acid.

11. *Copper Solution (Fehling's) for Sugars.*

Take of pure copper sulphate, . .	34·64 grammes.	*Dissolve.*
„ distilled water, ...	200 c.c.	
Take also of tartrate of sodium and potassium,	173 grammes.	*Dissolve.*
Solution of caustic soda (or caustic potash),	480 c.c.	

Mix the two solutions slowly, and dilute with distilled water to 1 litre.

1 c.c. is reduced by 5 milligrammes of either glucose or inverted sugar.

„ „ 6·67 „ of lactin (or milk sugar).

12. *Iodine Solution for Hydrogen Sulphide.*

Dissolve 6·35 grammes of iodine in 1 litre of distilled water by the aid of a little potassium iodide.

1 c.c. =0·85 milligramme of H_2S.

If a litre of water be taken for examination, the short factor for cubic inches per gallon is 0·164.

Starch is used as the indicator.

13. *Solution of Iron for Colorimetric Test.*

Dissolve 1 gramme of pure iron wire in nitro-hydrochloric acid; precipitate the ferric oxide with ammonia; wash the precipitate; dissolve in a little hydrochloric acid, and dilute to 1 litre.

1 c.c. = 1 milligramme of iron.

This is the strong solution.

For use it is diluted 1 to 100, so that

1 c.c. = 0·010 milligramme of metallic iron.
1 c.c. = 0·027 „ of iron phosphate.

14. *Dilute Acid Solutions* are generally 1 part of acid to 9 of distilled water, unless otherwise specified.

15. *Qualitative Solutions*, and, generally, solutions that are not titrated or graduated, are *saturated*, unless otherwise specified.

16. *Brucine Solution* (for *Nitric Acid*).—1 gramme of brucine to 1 litre of distilled water.

17. *Solution of Potassium Iodide and Starch* (for *Nitrous Acid*).

Potassium iodide 1 gramme, starch 20 grammes, water 500 c.c. Make the starch, filter when cold, and then add the potassium iodide.

This mixture does not keep well, and must be made fresh from time to time; or, the solutions 3 (*b*) and 3 (*e*) may be used instead.

18. *Solution of Gold Chloride* (for *Oxidisable Matter* in water).—One gramme of gold chloride dissolved in 1 litre of water.

19. *Solution of Cochineal* (for *Acidities* or *Alkalinities*).—Take 5 grammes of cochineal, bruised in a mortar, add 25 c.c. of spirit of wine and 500 c.c. of distilled water: filter. This solution is apt to become a little acid.

20. *Phenol-Phthalein Solution* (for *Acidities* or *Alkalinities*).—Take 5 grammes of the phenol-phthalein, and dissolve, with the aid of 25 c.c. of spirit of wine in 500 c.c. of distilled water.

21. *Use of Sikes' Hydrometer*, for ascertaining the strength of spirits.

A sample of the spirits to be tested is poured into a trial glass, and the temperature ascertained by means of a thermometer in the usual way. The hydrometer is taken, and one of the weights is attached to the stem below the ball: it is then pressed down to the 0 on the stem. If the right weight has been selected it will float up to one of the divisions on the stem. The number on the *stem* is then read off and added to the number on the *weight*; the sum is called the *indication*. The book of tables is then opened at the temperature first found, and the indication looked for in one of the columns: opposite it will be found the strength of the spirits *over* or *under* proof. If at the temperature 60° F. the *indication* is 58·8, then opposite this will be found zero, that is, the spirit is the exact strength of *proof*. If the indication is 50, then opposite that is 12·8, or the spirit is 12·8 *over* proof: if the indication is 70, then opposite is 18·9, or the spirit is 18·9 *under* proof. The meaning of these expressions is—(1) If the spirit be 12·8 over proof, then, in order to reduce it to proof, 12·8 gallons of water must be added to 100 gallons of the spirit: the resulting mixture will be proof; (2) if the spirit be 18·9 under proof, this means that 100 gallons contain only as much alcohol as 89·1 (*i.e.*, 100 – 18·9) of proof spirit: to raise it to proof it would have to be mixed with an equal quantity of spirit as much above proof as it is below it, so that $\frac{100-18\cdot9+118\cdot9}{2}=100$.

The *Adulteration of Food and Drugs Amendment Act*, 1879, allows brandy, whisky, or rum to be 25 degrees under proof; equal to 42·6 per cent. of absolute alcohol, volume in volume, or 34·1 per cent. of weight in volume. This gives a specific gravity of 0·947. Gin is allowed to be 35 degrees under proof, equal to 36·9 per cent. volume in volume, or 29·5 per cent. weight in volume of absolute alcohol. This gives a specific gravity of 0·956. Proof spirit contains 56·8 volume in volume, or 45·4 weight in volume of absolute alcohol., sp. gr. 0·920. The presence of sugar or extractives renders the use of the hydrometer fallacious unless the spirit is distilled off.

APPENDIX B.

METRICAL WEIGHTS AND MEASURES.

a. Length.

1 Metre	= 39·37	English inches		= 3·28 feet.
1 Decimetre	= 3·94	„	„	= (4 inches nearly).
1 Centimetre	= 0·39	„	„	= ($\frac{4}{10}$ inch nearly).
1 Millimetre	= 0·039	„	„	= ($\frac{1}{25}$ inch nearly).

N.B.—The *Latin* prefix indicates division.
The *Greek* do. do. multiplication.

1 Kilometre = 1000 metres = 1094 yards = $\frac{5}{8}$ mile (nearly).
1 Mile (English) = 1609 metres, or 1·609 kilometres.

b. Area.

1 Square metre	= 10·76	sq. feet	= 1542 sq. inches.
1 Square centimetre	= 0·154	sq. inches	= $\frac{2}{13}$ sq. inch (nearly).
1 Square millimetre	= 0·0015	„	= $\frac{1}{650}$ „ (nearly).
100 Square metres	= 1 are	=	119·7 square yards.
100 Ares	= 1 hectare = 11967·	„ „	= 2·47 acres.
100 Hectares	= 1 square kilometre = 247 acres = 0·386 sq. mile.		

c. Capacity.

1 Decimetre cubed = 1 litre = 1000 cubic centimetres = 61 cubic inches = 35·3 ounces = 0·22 gallon.
1 Cubic centimetre = 0·061 cubic inch.
1 Cubic inch = 16·4 cubic centimetres.
28·35 Cubic centimetres = 1·733 cubic inches = 1 ounce.
1,000,000 Cubic centimetres = 1000 litres = 1 cubic metre = 1 stere = 35·3 cubic feet.

d. Weight.

1 Cubic centimetre of distilled water at 4° C. (39°·2 F.) weighs 1 gramme.
1 Gramme = 15·432 grains.
1 Decigramme = 1·543 „ (= $1\frac{1}{2}$ grains nearly).
1 Centigramme = 0·154 „ (= $\frac{2}{13}$ grain nearly).
1 Milligramme = 0·015 „ (= $\frac{1}{65}$ grain nearly).
1 Kilogramme = 1000 grammes = 15432 grains = 2·2 ℔ *avoir.* = 35·3 ounces.
French *livre* and German *pfund* = 500 grammes = 1·1 ℔ = 17·6 ounces.
The German *loth* = $16\frac{2}{3}$ „ = $\frac{3}{5}$ ounce nearly.
1 ℔ *avoir.* = 453·5 grammes.
1 ton *avoir.* = 1018 kilogrammes.

APPENDIX C.

THERMOMETER SCALES.

$$\frac{\text{Centigrade}}{5} = \frac{\text{Réaumur}}{4} = \frac{\text{Fahrenheit}-32}{9}$$

	Centigrade.	Réaumur.	Fahrenheit.
Mercury freezes at	−40°·0	−32°·0	−40°·0
Zero of Fahrenheit,	−17·7	−14·2	0·0
Water freezes at	0·0	0·0	32·0
Water at its maximum density at	4·0	3·2	39·2
Mean temperature of London,	10·2	8·2	50·4
Mean temperature for specific gravities, &c.,	15·5	12·4	60·0
Mean temperature of Calcutta,	25·8	20·6	82·0
Mean temperature of the human body,	38·5	30·0	98·4
Alcohol boils at	78·3	62·7	173·0
Water boils at	100·0	80·0	212·0
Mercury boils at	360·0	288·0	600·0

APPENDIX D.

BAROMETER SCALES.

Standard pressure = 760 millimetres = 29·922 inches.
30 inches = 762 „
29·5 „ = 749 „
29 „ = 737 „
28·5 „ = 724 „
28 „ = 711 „
1 „ = 25·4 „

APPENDIX E.

1. *Table showing the Daily Yield of Water from a Roof with varying Rainfalls.*[1]

Area of House, 10 feet by 20 feet, or 200 square feet.					
Mean Rainfall.	Loss from Evaporation.	Requisite capacity of Tank.	Mean daily yield of Water.	Mean daily yield of Water in wettest year.	Mean daily yield of Water in driest year.
inches.	per cent.	cubic feet.	gallons.	gallons.	gallons.
20	25	100	4·3	6·7	3·2
25	20	135	5·7	7·5	3·9
30	20	145	6·8	9·4	4·5
35	20	155	7·9	11·0	5·0
40	15	165	9·7	13·1	7·2
45	15	170	10·9	14·2	8·6

For any other size of Roof or amount of Rainfall, the numbers will be proportional.

2. *Table showing the Distribution of* Positive *and* Negative *Errors, according to Number of Events.*

(*a*) 1 Event.

	Chances.
1 positive,	1
1 negative,	1
Total,	2

(*b*) 2 Events.

	Chances.
2 positive,	1
1 positive, 1 negative,	2
2 negative,	1
Total,	4

(*c*) 3 Events.

	Chances.
3 positive,	1
2 positive, 1 negative,	3
1 positive, 2 negative,	3
3 negative,	1
Total,	8

(*d*) 4 Events.

	Chances.
4 positive,	1
3 positive, 1 negative,	4
2 positive, 2 negative,	6
1 positive, 3 negative,	4
4 negative,	1
Total,	16

(*e*) 10 Events.

	Chances.
10 positive,	1
9 positive, 1 negative,	10
8 positive, 2 negative,	45
7 positive, 3 negative,	120
6 positive, 4 negative,	210
5 positive, 5 negative,	252
Carry forward,	638
Brought forward,	638
4 positive, 6 negative,	210
3 positive, 7 negative,	120
2 positive, 8 negative,	45
1 positive, 9 negative,	10
10 negative,	1
Total,	1024

In each case the number of chances corresponds to the coefficients of a binomial whose exponent is the number of events. Thus, with one event we have $(a+b)^1 = a+b$: with 2 events we have $(a+b)^2 = a^2+2ab+b^2$, and so on.

[1] From a paper by H. Sowerby-Wallis, F.M.S., on "Rainfall Collection," *Transactions of the Sanitary Institute of Great Britain*, vol. i., 1880 (Croydon Congress), p. 213.

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